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A Manufactured House
See *Toward a Science of Housing*, page 295

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THE SCIENTIFIC MONTHLY

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THE PROGRESS OF SUGAR RESEARCH

By ROBERT C. HOCKETT

Dr. Hockett (Ph.D., Ohio State, 1929) is on a five-year leave of absence from Massachusetts Institute of Technology to carry on his work as Scientific Director of the Sugar Research Foundation, a nonprofit organization with offices at 52 Wall Street, New York City. He has been a Fellow of the National Research Council, Associate Technologist on the staff of the U.S.P.H.S., Lecturer of the Swiss-American Foundation for Scientific Exchange, and Chairman, Division of Sugar Chemistry and Technology, American Chemical Society. He has published many research papers on the chemistry of sugars.

AN EVENT of exceptional significance for the progress of carbohydrate chemistry occurred in June 1943 when the producers and processors of cane and beet sugar supplying the United States market established the Sugar Research Foundation.

Although the organization is little more than three years old and many of its projects have been underway for less than two years, it may be profitable at this point to examine the accomplishments of the organization and perhaps indicate the course its future development will take.

As directed in the Certificate of Incorporation, the Foundation has devoted itself to a strictly scientific study of sugar with two primary objectives: to develop a better understanding of the role of sugar in human metabolism, and to explore the basic chemistry of the sugar molecule so that its potential industrial usefulness may be more fully realized. It is not concerned with sugar production and supplies or with legal and marketing problems.

The Foundation's purposes as outlined in the Certificate are as follows:

> To initiate, promote, assist, develop, maintain, conduct, and carry on, directly or indirectly, investigations, studies, and research relating to sugar, and any and all uses or possible uses of sugar, in any form whatsoever, and whether as a food or an ingredient of foods or beverages, or in industry or otherwise, including, without limiting the generality of the foregoing, the place and value of sugar in the human diet, its relationship to other foods, and its nutritional, dietary, industrial and other uses, purposes or effects, whether separately, or as an ingredient of or in combination or conjunction with other foods or substances:

This broad statement of purposes has been interpreted to include relevant studies in the numerous practical arts and technologies such as baking, preserving, confectionery, ice-cream manufacture, fruit-freezing, pharmacy, metallurgy, tanning, and the like; the investigation of by-products from the beet and cane plants; and also fundamental investigations in the scientific fields of nutrition, biochemistry, physiology, microbiology, and organic chemistry.

It has been the policy of the Foundation to provide for such studies by grants-in-aid to experts already well established in colleges, universities, and research institutes. Applications are received until April 1 of each year for consideration in relation to the fiscal year beginning on the following July 1. In general, grants have been planned to provide increased assistance for special projects in laboratories where guidance and direction, general facilities, and research tradition already exist. It is to be noted in particular that the Foundation employs very few persons directly. The experts who receive grants for the assistance of their research have been expected themselves to employ such personnel as they need for efficient prosecution of the tasks assumed. At the present time fifty projects have been supported, involving more than seven hundred thousand dollars.

M.I.T. laboratory. One of the organization's first undertakings was the establishment at the Massachusetts Institute of Technology of the Sugar Research Foundation Laboratory. Coordinated with the Department of Chemistry curriculum, advanced courses in carbohydrate chemistry are offered to graduate students. Under the direction of resident researchers, and with the assistance of full-time graduate specialists and part-time doctoral candidates, a five-year program has been laid out directed to exploratory and fundamental studies from which new uses for sugar as a chemical material may develop. A system of graduate fellowships makes possible the appointment each year of several research assistants from among the outstanding graduates of colleges and universities who wish to pursue graduate work in the field of carbohydrate chemistry. Such appointees, if they qualify as candidates for the doctor's degree according to the usual standards of the Massachusetts Institute of Technology, and if they maintain their standing, can generally be reappointed often enough to provide support for the entire graduate course. This plan is designed to help maintain the supply of trained carbohydrate chemists available to the sugar and allied industries.

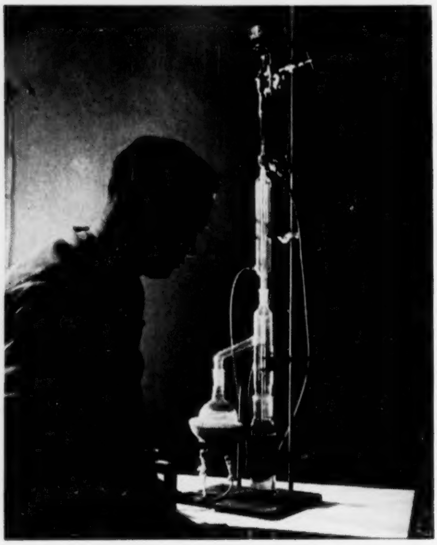


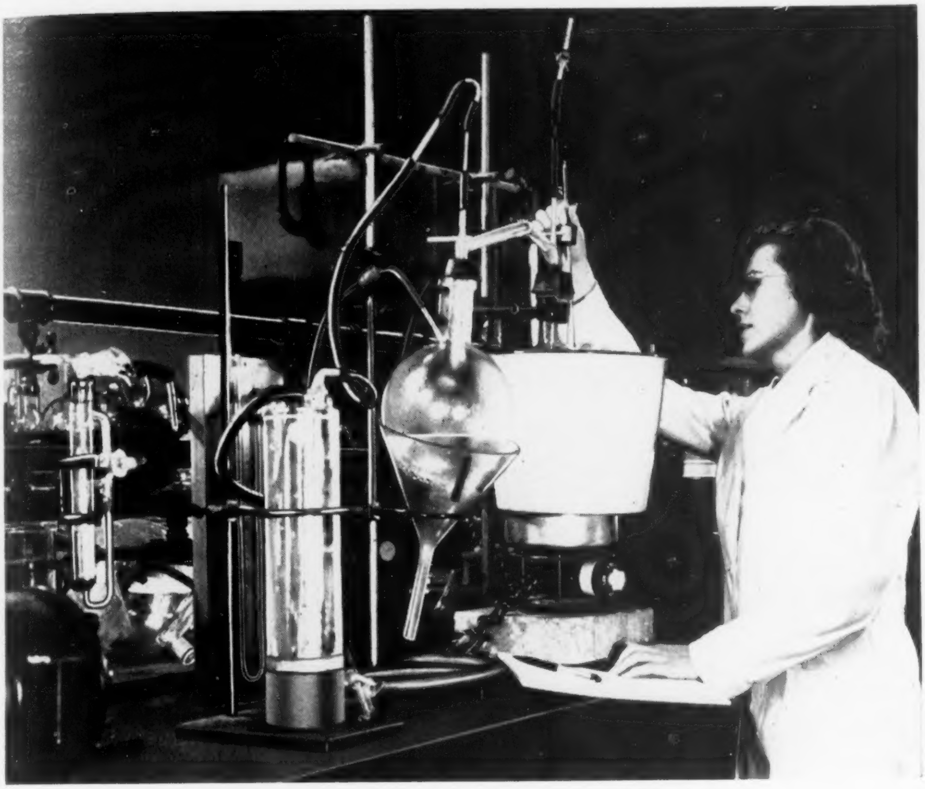
Photo by Arnold Morrison

LABORATORY RESEARCH

A MOTOR-DRIVEN SEPARATOR HAS PROVED VALUABLE FOR STUDYING SUGAR SEPARATIONS AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

Among the developments that are of some practical interest are considerable progress in the selective oxidation of invert sugar and the separation of sugars and sugar derivatives by two-phase liquid solvent extraction. Alcoholysis of sucrose has been studied as a basis for separating dextrose and levulose. Analytical methods based on lead tetraacetate have been further developed, and this substance has been made a powerful research tool. Dr. Lawrence Heidt has attained new efficiency in the control of sugar inversion, and the sterilization of such solutions by heat has been achieved without detectable decomposition.

Physiological studies. A notable volume of work has come out of the first project, that directed by Dr. Ancel Keys, of the Laboratory of Physiological Hygiene at the University of Minnesota, partially supported by



LABORATORY TECHNIQUE AT M.I.T.
MINIATURE VERSIONS OF SUGAR REFINERY VACUUM PANS ARE USED TO PROCESS SUGAR COMPOUNDS UNDER REDUCED AIR PRESSURE AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

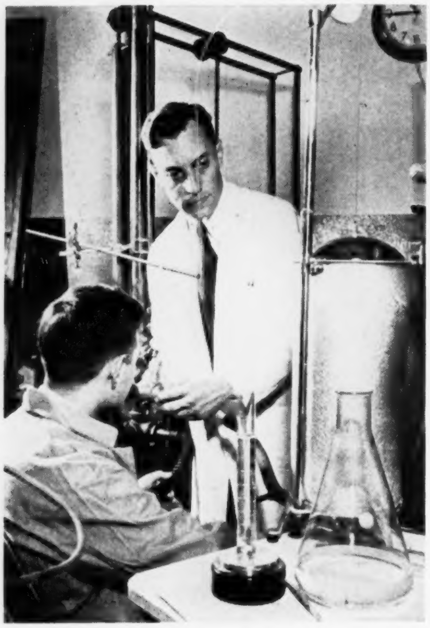
the Foundation. The purpose of Dr. Keys has been to study the metabolism in man of sugar and other related carbohydrates, with special reference to the use, digestion, and combustion of such carbohydrates as a source of energy for human work and activity, and to the requirements of vitamins, particularly thiamine and other members of the B complex, as affected by sugar and other related carbohydrates.

Seven research papers, to which some contribution has been made by the Foundation, have been published to date. One of the most significant—"Human Starvation and Its Consequences"—appeared in the *Journal of the American Dietetic Association*.

In recent years, there has been a great deal of discussion about dietary deficiencies, especially deficiencies of vitamins, minerals, and amino acids. Numerous workers have been engaged in experiments concerning the effects of such deficiencies and in describing the various symptoms and diseases that result from them.

On the other hand, very little accurate scientific work has been reported on the effects and symptoms of calorie deficiencies, in spite of the fact that many dietary surveys in recent years have shown calorie deficiencies to be widespread among the population. Because of the tremendous number of people all over the world who are suffering from insufficient food supplies, the effects of calorie deficiencies have assumed vital importance.

When it became apparent early in the course of the war that malnutrition and starvation would be inevitable, Dr. Keys



ANCEL KEYS

HE HAS USED HUMAN SUBJECTS AT THE UNIVERSITY OF MINNESOTA FOR INVESTIGATING THE VALUE OF HIGH-CALORIE DIETS IN THE REHABILITATION OF FAMISHED AND UNDERNOURISHED PEOPLE.

concentrated on the problem of calorie deficiency to discover the most effective means of rehabilitation. A search of the literature showed very little record of what happens to muscles and organs under conditions of starvation. Using volunteer conscientious objectors rather than laboratory animals to expedite the study, Dr. Keys allowed the subjects to eat only what was served to them from the laboratory kitchens. The food was carefully weighed and imitated closely the European diet. Nutritionally, this diet was not too bad, for it consisted of turnips, coarse cereals, and potatoes, with small amounts of meat, fish, cheese, or eggs, supplying a fairly good quantity of the vitamins and essential protein. Its chief deficiency was in food energy, that is, calories, so that the subjects lost approximately 25 percent of their weight. At every stage of the six months' period, tests were made.

The effects of calorie deficiencies were marked. Muscles shrank and the men became too weak to exercise. The heart decreased in size, and the rate of beat dropped to as low as one-half the normal. Sensitivity to cold was noted, and the men complained of feeling depressed and worried. At the same time intelligence, memory, reasoning power, and the function of the senses were unimpaired. Careful examinations revealed no signs of vitamin deficiency. For recovery it was found that calories were of prime importance. Various kinds of amino acid concentrates failed to speed up rate of recovery, nor were the effects of large doses of vitamins noticeable. Intravenous feeding not only failed to help but was actually dangerous because of the added strain on weakened hearts.

During the first few weeks 3,000 calories a day were needed. Later, 3,500–4,000 calories a day for several months resulted in marked improvement. Even with extra calories, however, recovery was slow, with only 80 percent recovery attained after six months of special feeding.

Thiamine requirements. Another phase of Dr. Keys's investigations has increased our knowledge of the human requirement for Vitamin B_1, thiamine. It was this vitamin that caused a considerable flurry of excitement several years ago when it was found that American diets do not contain much more thiamine than the Oriental diets that often cause beriberi. Some concern arose as to whether Americans generally were not on the fringe of deficiency, and several authorities urged a move to replace refined carbohydrates in part by those containing thiamine.

Accumulating evidence has changed the picture considerably. First, as compared with the Orientals, we are heavy fat consumers, and fat does not require thiamine for its combustion to the extent that carbohydrates do. Second, Orientals eat a great deal of fish, much of it raw, and raw fish has been found to contain an antimetabolite that spe-

cifically destroys thiamine. Hence, as compared with the Orientals, we need less thiamine and lose less through destruction. With respect to determining the requirement, Dr. Keys has made a most significant contribution. As a result of all these observations, the National Research Council has revised downward its Recommended Daily Allowance for thiamine. The new figure, which contains a liberal margin of safety for normal persons, represents a daily intake not difficult to attain by selecting a generally good diet in which sugar need not be restricted specifically.

It does not follow that new foods high in thiamine would not be a valuable and welcome addition to American diets. One of the most promising new foods of this class is edible yeast. The Foundation is taking an increasing interest in yeasts, since they can be produced from by-product molasses and are capable of providing needed protein and B-complex vitamins for our diets. The study of edible yeasts has only begun, and there is a distinct possibility of finding strains with higher vitamin content, better flavor, and superior protein.

Dr. Keys has also confirmed the older claims that carbohydrate is somewhat more rapidly effective as an energy source than fat or protein. He has disproved the claim that sugar, in reasonable concentrations, delays the emptying of the stomach and has shown that high-carbohydrate meals are just as "lasting" as meals of other types. The last finding is contrary to the claims that led to wide propaganda for high-protein breakfasts.

This last question has formed the subject of extensive studies by Dr. John Haldi, of Emory University. Using large numbers of healthy young medical students, he has given high-carbohydrate breakfasts alternately with high-protein breakfasts but has found no mid-morning hypoglycemia following either type, either when sedentary occupations are pursued or when severe exercise is

Photo by Arnold Morrison

SUGAR CHEMISTRY AT M.I.T.

WHOLLY CHEMICAL STUDIES OF SUGAR AND SUGAR DERIVATIVES, COORDINATED WITH ADVANCED COURSES IN CARBOHYDRATE CHEMISTRY, ARE BEING CARRIED ON UNDER A FIVE-YEAR PROGRAM AT M.I.T.

undertaken. He concludes that hypoglycemias are the result of disturbed metabolism rather than of diet. Related experiments upon the efficiency of factory workers are now underway.

Dramatic discoveries have been reported by Dr. I. M. Rabinowitch, of the Montreal General Hospital, who has observed the actual speed at which sugars taken by mouth reach the blood stream. Although sucrose taken by mouth must be inverted, or hydrolyzed, in the body during the course of absorption, it actually provides glucose to the blood stream more rapidly than does dextrose, as such, taken by mouth, even though this simpler sugar has often been considered capable of direct absorption "without digestion." Moreover, sucrose has a characteristic and specific effect upon the inorganic blood phosphate, which tends to emphasize the individuality of familiar sugar and to show that it cannot be regarded as a mere mixture of *d*-glucose (dextrose) and *d*-fructose (levulose). This work has shown

again the desirability of pressing investigations into the metabolism of sucrose, or ordinary sugar.

Dr. Rachmiel Levine, of Michael Reese Hospital, Chicago, has studied the metabolism of levulose specifically and has shown that it is used directly by many tissues, particularly by the liver, which removes *d*-fructose from the blood two and one-half times as fast as dextrose. For the entrance of fructose into the tissues, insulin appears to be unnecessary, though once glycogen has been formed the normal utilization of this reserve carbohydrate does require the agency of insulin. A new test for liver function based upon the response to fructose injection has been developed.

Dental research. The problem of tooth decay requires a tremendous intensification of research effort if the factors contributing to susceptibility and resistance are to be understood and controlled effectively. Leading public health authorities recognize both the importance and the great complexity of this problem and emphasize the importance of broadening the basis of caries research.

Although the contribution that can be made to dental caries research by the Sugar Research Foundation is necessarily very small, the hope has been expressed that it may have an importance out of proportion to its monetary value as an example that may encourage other agencies to give attention to this field of study.

Particular attention has been given to the selection of projects for support in order that the limited funds available for this field may be as valuable and effective as possible. Many studies of caries have been invalidated by a lack of attention to statistical method or by the use of inadequate numbers of subjects. Others have been impaired by the use of short cuts such as the measurement of "indirect indices of caries activity" instead of the direct measurement of the cavities actually formed in animals under specific regimens. The projects aided by the Foundation employ no such indirect indices, since these introduce, at the least, an element of doubt and of possible controversy. The methods of investigation approved by the Foundation by appropriation of grants-in-aid are of the relatively slow and expensive type, but they provide the best promise of sound progress in the long run.

To detect significant differences in the caries incidence rate within a group of individuals subjected to special conditions, it is necessary to know the extent of the variations that might have occurred if they were left alone. Dr. Julian D. Boyd has made very careful studies of the caries records of Iowa children for over two years in order to determine this degree of natural variability. He was equally concerned to find an institutionalized group of children who could be subjected to complete dietary control without errors, exceptions, or accidents. Such a group has finally been found, and a comprehensive experiment is getting underway to show whether truly superior diets containing

Photo by Arnold Morrison

DENTAL RESEARCH

A STUDY OF METHODS FOR REDUCING THE INCIDENCE OF CARIES IN CHILDREN BY TOPICAL APPLICATIONS OF SODIUM FLUORIDE SOLUTIONS IS BEING CARRIED OUT AT TUFTS COLLEGE DENTAL SCHOOL UNDER DR. BASIL G. BIBBY AND HIS COLLABORATORS.

adequate protein, vitamin D, fluoride, and other factors will give caries control without specific relation to the level of sugar consumption.

A team of well-qualified experts has been assembled at the Harvard School of Dental Medicine. Colonies of cotton rats, hamsters, and monkeys have been established, and systematic studies of the factors affecting caries have been begun. One study relates specifically to raw sugar as compared with refined. Preliminary reports show no significant difference in the animals fed the two types of sugar. This finding, if confirmed, tends to show that there is no specific inhibitory factor in raw sugar and also that caries is not a simple calcium deficiency.

A great contribution from the Harvard staff is completion of a critical survey of the medical literature on the relation between diets and caries. This survey is designed to show which results reported to date are reliable and to indicate what conclusions regarding caries may be considered as established. This review is to become part of a comprehensive analysis of the literature on dental caries research that is being compiled under the auspices of the National Research Council.

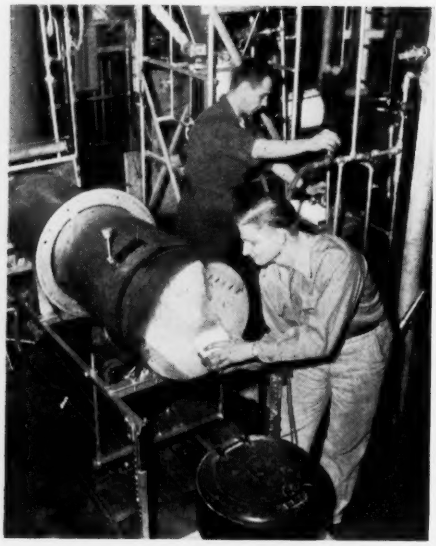
Experiments investigating the effectiveness of restoring normal fluoride content of children's teeth by the topical application of fluoride solutions are promising. Under Dr. Basil G. Bibby, of Tufts College Dental School, and his collaborators, noticeable reductions in the caries incidence among treated children have been observed.

Levulose extraction. In the field of applied

Photo by Arnold Morrison

DIETARY STUDIES ON COTTON RATS

A TEAM OF SPECIALISTS AT THE HARVARD SCHOOL OF DENTAL MEDICINE HAS BEEN STUDYING THE EFFECTS OF DIET ON COMPOSITION OF TEETH AND INCIDENCE OF CARIES IN COLONIES OF COTTON RATS.



A PILOT PLANT

EXTRACTING LEVULOSE FROM SUCROSE AT THE ENGINEERING EXPERIMENT STATION OF THE UNIVERSITY OF COLORADO TO MAKE THIS HITHERTO SCARCE CHEMICAL AVAILABLE FOR RESEARCH.

research, levulose, the simple sugar of high sweetness, is now becoming available for the first time in sufficient quantities for experimental work by physicians, physiologists, biochemists, and others, through the project supervised by Dr. Carl W. Borgmann and Mr. M. M. Reynolds, of the Engineering Experiment Station at the University of Colorado. The pilot plant, which has been in production for some time, uses an ion-exchange process to obtain levulose from common sugar and represents the only commercially feasible method in actual operation. Satisfactory yields of levulose have also been obtained from beet molasses.

Although levulose, often referred to as fructose, or fruit sugar, is an important natural sugar with many potential uses in food industries, there has never been enough of it for extensive study because of the high cost and difficulty of separating it by traditional methods. The method used in the pilot plant now in operation is relatively cheap and simple. Another advantage of this process is that it achieves a true separation without destroying the dextrose fraction. Studies are being made to estimate costs and technical problems involved in actual manufacture on a large scale.

In addition to its high sweetness, levulose has a higher solubility than either sugar or dextrose. Recent research also suggests that it may have unique and important physiological effects. Lack of availability in the past has hindered research, but studies are now being carried on to find out more about the storage of levulose in the body, its use by various organs, and its effect on blood lactic acid.

It is known that levulose is absorbed and stored by the liver at two and a half times the rate of dextrose. In the liver it is transformed into glycogen and, as such, provides readily available blood sugar reserves. Glycogen also appears to have a protective action, possibly preventing cirrhosis and guarding the liver against toxic agents.

Levulose also evidently plays an important but unknown role in early life. English investigators have recently discovered that 90 percent of the blood sugar of embryonic lambs consists of levulose and that this sugar occurs in seminal fluid.

Industrial projects. There is another development that promises to be of commercial value. In the Eastern Regional Laboratory of the U. S. Department of Agriculture, Drs. Nichols and Yanovsky have considerably extended the investigation of the allyl ethers of carbohydrates. Such ethers were reported as long ago as 1923 by Tomecho and Adams, but they now appear much more interesting because of the availability of allyl chloride upon a large scale.

Allyl sucrose when unpolymerized can be dissolved in organic solvents such as alcohol, chloroform, acetone, benzene, or toluene. If applied to a surface such as wood, metal, or paper, the solvent will evaporate to leave a smooth coating of high gloss. Heat treatments produce a coating resistant to all known solvents, hot oils, and reasonably

J. W. LeMAISTRE IN HIS LABORATORY

HE SUPERVISES A PROJECT AT THE INDUSTRIAL RESEARCH INSTITUTE OF THE UNIVERSITY OF CHATTANOOGA ON INDUSTRIAL USES FOR SUGAR AND SUGAR PRODUCTS.

concentrated acids and alkalies. These coatings are said to withstand temperatures up to 400° F. The Sugar Research Foundation has recently concluded an agreement with the Department of Agriculture under which we have placed a Research Fellow of our own selection at the Eastern Regional Laboratory to concentrate upon further study of these coatings. A number of improvements have already been worked out under this cooperative study. Methods for "bodying" allyl sucrose to favorable brushing consistency have been perfected, and a spontaneously drying product that requires no heat curing has been developed. It is hoped that pilot-plant operations will make samples generally available within six months.

New frozen fruit products using sugar have been described by Dr. W. V. Cruess, of the University of California. With his colleagues he has also studied the blanching of fruits in isotonic sugar solutions and the syrup concentrations best suited to the preservation of color, flavor, and soluble nutrients in various types of fruits.

The fractionation of molasses has made progress under Drs. F. W. Zerban and Louis Sattler, of the New York Sugar Trade Laboratory, as well as under Dr. Wolfrom and his associates at Ohio State University where new chromatographic adsorption methods for separating sugar acetates have been developed. At the University of Utah, glucose mercaptals have been obtained in pure crystalline form by using both sugar and molasses as the starting materials.

Dr. Carl Neuberg, of New York University, has perfected a method for speeding up

the fermentation of sugar to glycerin from 5–7 days to 14–18 hours and is engaged at present in a similar study of molasses.

Drs. Andrew Van Hook and Elizabeth Roboz at the University of Wyoming have prepared light-colored pectins from dried beet pulp and have produced *l*-arabinose and galacturonic acid salts from the same material. The use of ion-exchange resins for de-ashing pectin is being studied. Dr. Van Hook has continued studies on the kinetics of sugar crystallization from real and synthetic massecuites and has shown the independence of crystallization rates from diffusion and viscosity. The effects of natural impurities on crystallization are being studied.

It is expected that findings from a number of other projects will soon reach the publication stage, and that with the termination of some of these studies other projects under consideration for some time can be initiated.

Award program. To supplement its own coordinated program of research through grants-in-aid, the Foundation has stimulated research and inquiry into sugar by establishing a series of prizes in recognition of outstanding discoveries or the development of original knowledge about sucrose. These awards, administered by the National Science Fund of the National Academy of Sciences, are open to scientists of all countries. Four intermediate annual awards of $5,000 and a Grand Award of $25,000, to be given in 1950 for the most important disclosure in the preceding five-year period, have been

MICE ARE USED FOR VITAMIN STUDIES

IN THE DEPARTMENT OF PHYSIOLOGICAL CHEMISTRY OF THE YALE UNIVERSITY MEDICAL SCHOOL SURVEYS HAVE BEEN MADE OF THE VITAMIN CONTENT OF VARIOUS NEW PRODUCTS OF THE SUGAR INDUSTRY.

announced. The first award of $5,000 was shared by Drs. W. Z. Hassid, H. S. Barker, and M. Doudoroff, of the University of California, Berkeley, for the enzymatic synthesis of crystalline sucrose, published in 1944.

The discovery of a method by which crystalline sugar can be synthesized enzymatically is significant, not because of commercial possibilities for increasing sugar supplies—for it has none—but because of its scientific implications. Its disclosures of a method of sugar synthesis through the action of living organisms, and also the details of the reversal of this action, that is, the breakdown of sugar into its simpler components, are both important. Most significant of all is the fact that this new synthesis renders possible new experimental approaches to the problem of sugar metabolism.

For a long time enzymes have been known that can cause the sugar molecule to combine with water and to break it down into its simple components, dextrose and levulose. Many enzymes work in reverse, but until now the familiar sugar-splitting enzymes had never been observed to bring about a recombination of dextrose and levulose into sugar. Now by means of an enzyme elaborated by *Pseudomonas saccarophila* sugar has been obtained for the first time directly from dextrose phosphate and levulose.

The very common and easy splitting of sugar into dextrose and levulose has led most plant and animal physiologists to think of sugar as little more than a loose combination of the two simpler hexoses, dextrose and levulose. They have not been greatly concerned with sucrose, as such, because it has been expected that sucrose would show little unique or individual behavior but would break down under almost any ordinary physiological environment into the simpler hexoses and then act just like a mixture of the two. Consequently, both plant and animal physiologists have been inclined to study dextrose rather than sucrose in connection with physiological problems.

The lack of commercial availability of levulose has caused this half of the sucrose molecule to be relatively neglected even though, as half of sucrose, such an omission obviously constitutes a serious hiatus in the complete study of sucrose metabolism.

However, the problem does not reduce so simply to a mere study of the two breakdown sugars, for levulose, as the free sugar, occurs largely as a relatively stable 6-membered ring compound (the pyranose form), whereas it is definitely proved by the organic chemists that in sucrose it occurs combined as a less stable, and probably more reactive, 5-membered ring form (the furanose form). This form has not been isolated in a free state. There is every reason to expect that this active form, when liberated from the sucrose molecule by enzymatic action, might give very different and yet very fundamental physiological reactions that could not be obtained through the use of simple mixtures of invert sugar (since the latter consists of free dextrose and *free* levulose). It is also possible that the dextrose half of the sucrose molecule, when first liberated from sucrose, may be in a more reactive state than its normal condition in free dextrose. There is not, however, as clear-cut evidence to indicate such a difference for dextrose as there is for levulose.

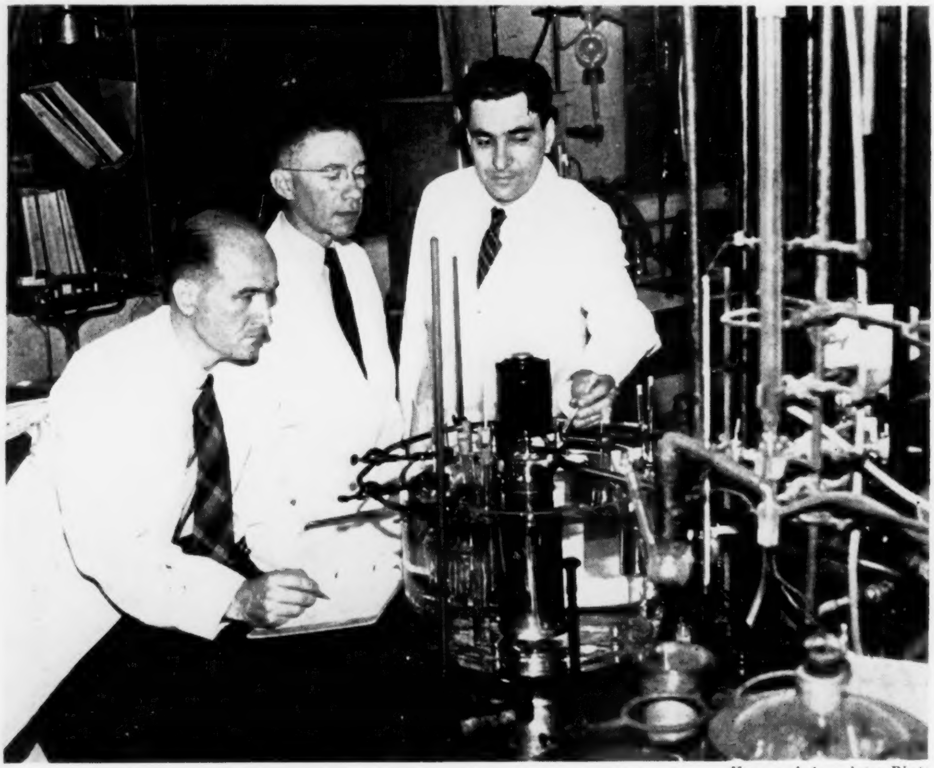
The net result of these facts and a consideration of the bond energy in the link between the two simple sugars in sucrose is that it is not justifiable to assume, as has been generally done in the past, that the behavior of sucrose in human metabolism can be successfully studied by observing mixtures of dextrose and levulose, that is, invert sugar, or that the behavior of either half of the sucrose molecule can necessarily be predicted by the study of either dextrose or levulose individually.

In order to determine what actually happens to the two sucrose fragments in the body, it is necessary to observe the behavior of these individual fragments during the

course of human metabolism. But, since either fragment may be converted to glycogen (blood sugar), via partially unknown mechanisms, it has not been possible to distinguish adequately one fragment from the other in their final utilization.

Using "tracer" technique, with dextrose or levulose prepared synthetically to obtain an atom per molecule of one of the carbon isotopes, it will be possible to follow the metabolism of these compounds through the various human organs. As pointed out above, however, results so obtained would *not* necessarily or even likely be expected to be identical with the behavior in the body of the two individual halves of the sucrose molecule. The only way to ascertain definitely the behavior of the fragments of the sucrose molecule in vivo would be to use "tagged" atoms in first one and then the other half of the molecule. But to do this, and to know in which half of the molecule the tagged atoms are located, would require the synthesis of sucrose from tagged dextrose or levulose of known origin; that is, it would be necessary to know which one contained the tagged atoms.

Hassid, Doudoroff, and Barker have actually made two important contributions. The first is the synthesis of sucrose; the second, which also serves to emphasize the uniqueness of sucrose, is their earlier and basic discovery that the enzyme from *Pseudomonas saccharophila*, which is capable of



Haas and Associates Photo

H. A. BARKER, H. Z. HASSID, AND M. DOUDOROFF

IN THE LABORATORY AT THE UNIVERSITY OF CALIFORNIA WHERE THEY WORKED OUT TECHNIQUES FOR THE FIRST RECOGNIZED ENZYMATIC SYNTHESIS OF SUCROSE. FOR THIS WORK THEY RECEIVED THE FIRST ANNUAL $5,000 SUGAR RESEARCH AWARD GRANTED BY THE NATIONAL SCIENCE FUND.

splitting sugar, does not form a simple mixture of dextrose and levulose. This enzyme requires phosphate in order to function, and it brings about a direct splitting of sucrose into levulose and a dextrose phosphate. The fact that something other than a simple dextrose-levulose mixture is formed again emphasizes the individuality of sucrose and that it may behave differently from simple invert sugar. This further indicates the need for much specific study of sucrose in the field of physiology.

Other phenomena that have recently been observed are in accord with the evidence that sucrose and invert sugar are by no means equivalent physiologically. We have mentioned the finding of Rabinowitch, who has shown that sucrose taken by mouth seems to raise the dextrose level of the blood faster than either dextrose taken by mouth or mixtures of dextrose and levulose. On the older theory that sucrose and invert sugar are physiologically equivalent, this fact cannot be explained. However, it fits in perfectly with the foregoing factual discussion, which shows why sucrose and invert sugar might be expected to behave differently.

Furthermore, should it prove to be true that sucrose is cleaved, in the body, directly to levulose and dextrose *phosphate*, as Hassid, Doudoroff, and Barker have found, instead of to free dextrose, then a mechanism for the difference observed by Rabinowitch would be at hand. It is known that all sugars must combine with phosphoric acid in the process of absorption through the intestinal wall. Hence, a cleavage of sugar to dextrose phosphate might expedite the process of getting sugar to the blood stream and give the disaccharide an actual advantage over dextrose taken as such.

It has also been observed by Robbins and by Went that excised tomato roots will grow well in cultures containing essential nutrients and sugar. They grow better in sucrose solutions than in solutions containing equivalent amounts of dextrose, levulose, or *mixtures of these two*.

The over-all effect of these studies is to create new consideration for the unique characteristics and specific properties of sucrose as a distinct and individual substance, which is not to be regarded as a mere mixture but as a compound requiring more extensive and intensive study in the fields of plant and animal physiology.

Dr. Carl F. Cori, Professor of Biochemistry at Washington University, St. Louis, Mo., and Dr. Gerti Cori were awarded the Second Sugar Research Award for their achievements in the study of carbohydrate metabolism in the animal body. This distinguished series of researches, extending over a period of twenty years, is so well known that it will be given no further exposition here.

Scientific Reports. The scientific literature abounds with reference to the uses of sugar for various purposes, in medicine, in the arts, and in the food and other industries. Very little of this material has been systematically collected and organized in the past. To fill the need for such organized and classified information concerning the numerous and varied uses of sucrose, the Foundation is undertaking to issue a series of Scientific Reports prepared by specialists in various fields.

Eight Reports in this series have been published:

1. *Sugar and Sugar By-Products in the Plastics Industry*, by Louis Long, formerly Research Associate in Chemistry, The Massachusetts Institute of Technology.
2. *Intravenous Administration in Clinical Practice*, by C. Jelleff Carr, Associate Professor of Pharmacology, University of Maryland Medical School.
3. *The Utilization of Sugar Cane Bagasse, For Paper, Boards, Plastics, and Chemicals*, An Annotated Bibliography edited by Clarence J. West, The Institute of Paper Chemistry, Appleton, Wis.
4. *Invertase*, A monograph by Carl Neuberg, Research Professor of Chemistry, New York University, and Irene S. Roberts, Dayton, O.

5. *The Uses and Functions of Sugar in Pharmacy*, by Paul S. Pittenger, Vice President in Charge of Quality Control, Sharp & Dohme, Inc., Philadelphia, Pa.
6. *Bacterial Polysaccharides*, by Taylor H. Evans, Research Chemist, Dominion Rubber Co., Ltd., and Harold Hibbert, late Professor of Industrial and Cellulose Chemistry, McGill University.
7. *Chemical Compounds Formed from Sugars by Molds*, by Bernard S. Gould, Associate Professor of Biochemistry, The Massachusetts Institute of Technology.
8. *Levulinic Acid as a Source of Heterocyclic Compounds*, by Avery A. Morton, Professor of Organic Chemistry, The Massachusetts Institute of Technology.

Two Technological Reports have also been issued:

1. *Patents on the Reactions of Sugars*, A digest by Alvin Guttag, Examiner, U. S. Patent Office.
2. *The Color Problem in Sucrose Manufacture*, by F. W. Zerban, Chemist in Charge, The New York Sugar Trade Laboratory, Inc.

These Reports, as well as the many papers already published by project directors in scientific journals, and the participation of project directors in numerous scientific meetings and symposia, have attracted the interest of individuals and groups in scientific circles here and abroad and resulted in the establishment of effective liaison between the Foundation and workers in related fields.

Even with the present world-wide shortage of sugar and the war-swollen output of certain other chemicals, the amount of sugar produced is still ten times greater than the next largest pure organic chemical. When a normal supply situation obtains and the basic facts about sugar are better understood, this cheap substance will become increasingly useful as a raw material.

Science is more and more turning its attention to utilization of the carbohydrates. It is our hope that the Foundation's fundamental studies will help to lay the necessary groundwork and make tangible contributions for the development of this promising field.

ADVANCE REGISTRATION

114th Meeting of the A.A.A.S., Chicago, December 26–31, 1947

Those planning to attend the Chicago Meeting of the Association, December 26–31, may register now by sending the correct registration fee ($2.00 for members and college students, $3.00 for nonmembers) to the Washington office of the Association, 1515 Massachusetts Ave., N. W. The *General Program* will be mailed on December 1 to all who register before that date, in time to study its contents and decide at leisure which of the many hundreds of sessions and special functions they may most profitably attend. Moreover, they will be saved the time of registering during the meeting, and their names will be included in the special directory of registrants that will be available for inspection in all the headquarters hotels.

The *General Program* will list the papers of the sections and societies meeting with the Association, including the time and place of each session. It will also contain announcements regarding general sessions, the International Science Exhibition, eating facilities, transportation, mail and messenger service, and a directory of speakers and presiding officers. Readers will find the Summary of Sessions most useful.

Registration fees have been received since August 15, and they will be accepted for mail distribution of the *General Program* until December 10. Payments received after that date will be held and placed on file on December 26 at the main registration center located adjacent to the Exhibition in the Stevens Hotel. Upon identification, registrants will be given a copy of the *General Program*, and their registration cards will be placed in the Visible Directory. To avoid delay in receipt of your copy of the program during the Christmas mailing rush, please send your registration fee in time for it to reach the Washington office before December 1.

THE MYSTERY OF THE MIMA MOUNDS

By VICTOR B. SCHEFFER

At present in Alaska in charge of research on the fur seal herd, Dr. Scheffer (Ph.D., University of Washington, 1936) is a biologist in the U. S. Fish and Wildlife Service, with headquarters in Seattle. He has specialized in studies of marine mammals; as a hobby he has delved into the giant earth mounds discussed below.

ON THE prairies of western Washington near the southern tip of Puget Sound are scattered thousands of large earth mounds whose origin has puzzled observers for more than a century. On Mima Prairie some of the mounds are higher than a man's head and have a content of 50 cubic yards. The mounds are smooth and round, like great spheres nearly buried in the earth. In many cases, the hollows between the mounds are filled with cobblestones up to the size of a football. In the spring of the year, when the mounds are covered with white-and-yellow daisies and green bracken ferns, they stand out clearly from their duller surroundings.

Wherever a mound has been sliced open by a roadway, a peculiar cross section is revealed. The typical mound is made up of soft black prairie silt mixed with pebbles up to the size of a walnut. The mound rests in a slight depression, or bed, in coarse, stratified glacial gravel, which continues downward for an unexplored distance. Thus, the typical mound is a biconvex lens, with the greater curvature exposed to the sky and the lesser curvature pressed against the gravel. At the base of the mound, armlike structures of black silt extend into the gravel. These have been called "mound roots" by certain investigators.

The origin of the mounds has long been

PROFILES OF MIMA MOUNDS SIX TO SEVEN FEET HIGH
IN THE FOREGROUND THE MOUNDS HAVE BEEN REMOVED BY FARM MACHINERY.

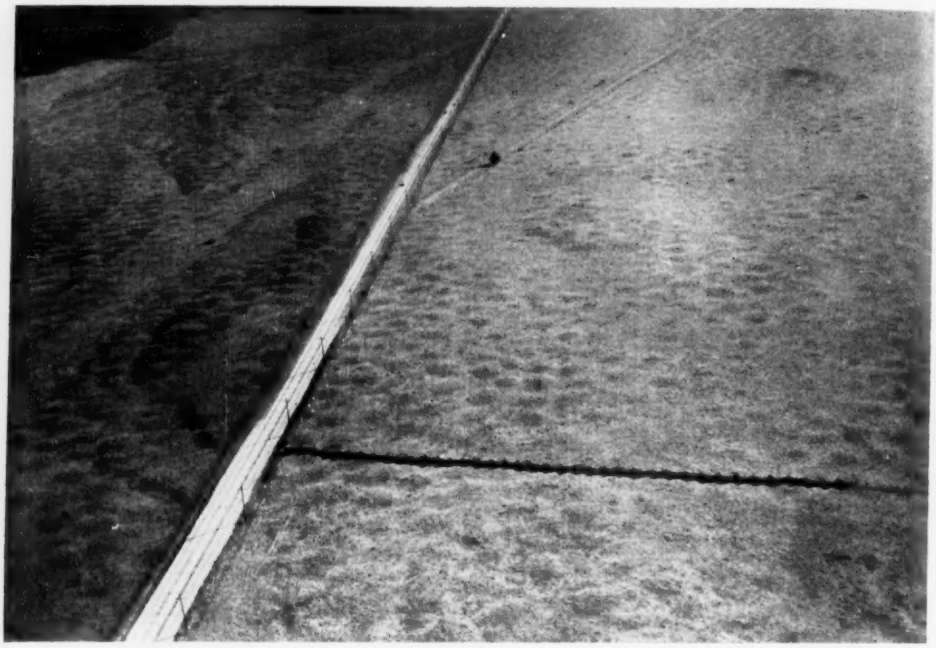


Photo by Army Air Corps

AN AIR VIEW OF MIMA MOUNDS

MOUNDS ON A GLACIAL OUTWASH PRAIRIE NEAR TENINO, WASH., AS SEEN FROM A LOW ALTITUDE.

disputed. A few years ago, a student at the University of Washington suggested a novel theory to account for the mounds and invited me to join him in a search for supporting evidence. How we approached the problem and attempted to fit our findings into a convincing pattern has been described in a preliminary paper.[1]

As we delved into the mystery of the Mima Mounds, it dawned on us that these formations are kindred to similar, though less spectacular, mounds strewn by the millions over the Western states from the Mexican border to northern Washington. Thus, the theory accounting for the mounds of Puget Sound—which we now accept—embraces also the countless mounds of similar shape and structure in the Western states. Because of certain peculiar features, Mima Prairie has served as a Rosetta stone in explaining the origin of other mound prairies.

MORE than a century ago mound prairies drew the attention of travelers in the new West. In July 1842, Commander Charles Wilkes made a special trip to "Bute Prairie," south of Olympia, Wash., and dug into three of the mounds in an attempt to unlock their secret.[2] He finally concluded that "they bear the marks of savage labour, and are such an undertaking as would have required the united efforts of a whole tribe." As indeed they would!

On the famous railroad survey of 1853–56, naturalists Gibbs and Cooper examined some of the mounds, and Gibbs suggested that "they might have been produced by the immense growth of the 'giant root,' (*Megarhiza* (*Echinocystis*) *Oregana*), forming a nucleus around which the soil has been gradually washed away." Cooper—a more conservative scientist—believed that the mounds were perhaps the result of eddy and whirlpool action at a time when the prairies were submerged beneath Puget Sound.[3] When Gibbs returned to the East he described the mounds to Louis Agassiz, who

"unhesitatingly" pronounced them the nests of a species of sucker. Professor Agassiz may be forgiven this opinion in view of the fact that he had not seen the mounds, some of which rise to a height of seven feet.

Joseph LeConte, geologist of the University of California, first saw the Puget Sound prairies in 1871. He was the first to point out the similarities among the mounds in California, Oregon, and Washington and he tried to show that their origin was due to "surface erosion under peculiar conditions."[4] As he reconstructed their geological history, the prairies were left by a retreating body of water with a blanket of fine topsoil and a coarse subsoil; erosion started to remove the finer topsoil everywhere but in certain spots; weeds, shrubs, and ferns immediately seized upon these spots, or islands, and anchored the soil; then when the climate grew drier, vegetation was able to survive only on the higher (and richer) islands while erosion continued to gnaw at their bases.

Interest in the American earth mounds was aroused in faraway England. Geologist Alfred R. Wallace discussed a letter from his brother in California describing the "hog-wallow" region of the San Joaquin Valley.[5]

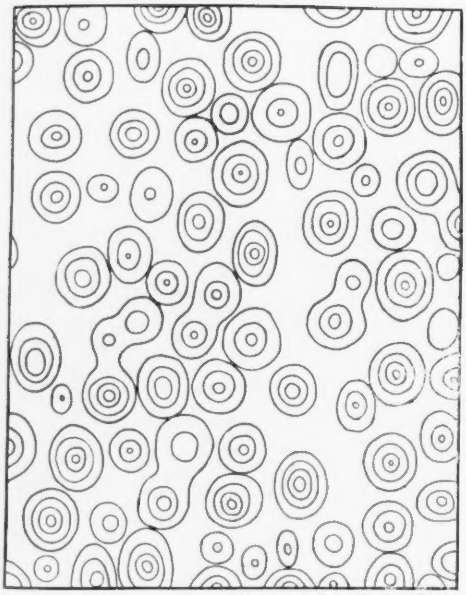
> The surface thus designated [he wrote] may be represented on a small scale by covering the bottom of a large flat dish with eggs distributed so that their longer axes shall lie at various angles with one another, and then filling the dish with fine sand to a little more than half the height of the eggs.

The California brother attributed the mounds to "innumerable rills that issued from the retiring sheet of ice" of a glacier long since disappeared. (It is now well established that the San Joaquin Valley was at no time covered by ice.

Soon afterward, G. W. Barnes discussed the small hillocks that lie on the old sea terraces back of San Diego.[6] He concluded that the San Diego mounds were produced—and

MIMA PRAIRIE, THURSTON COUNTY, WASH.

THIS IS THE TYPE LOCALITY OF THE MIMA MOUNDS.



Courtesy of J. Harlan Bretz

MOUND TOPOGRAPHY

CHARACTERISTIC ARRANGEMENT OF MOUNDS ON MIMA PRAIRIE; CONTOUR INTERVAL, TWO FEET.

are still being produced—by a peculiar combination of wind and water erosion in the presence of vegetation, as follows: prevailing winds deposit dust and leaves at the base of a shrubby desert plant; rain-water erosion cuts faster at the base of the mound than at the top; the shrub eventually dies; and, "deprived of its protection, the summit is reduced and the base widened as it is lowered, till finally a remnant of the deposit has become so assimilated and compact as to constitute a more permanent summit." Accompanied by Dr. K. O. Emery, I examined the San Diego mounds in 1943 and found them very like the mounds of Puget Sound.

In a résumé in 1905, J. C. Branner disposed of a number of theories to account for the Western mounds and concluded: "The ant-hill theory seems to me the most plausible, but with our present knowledge it is far from satisfactory."[7] He also dwelt on the concept that the mounds are the result of differential solution and concretion on a large scale.

Marius Campbell, of the Geological Survey, followed shortly with a paper summarizing the various hypotheses for the mounds that lie on the plains from Arkansas to the Pacific coast.[8] He showed that naturalists had laid the origin of the mounds to the agency of humans, burrowing mammals (ground squirrels, gophers, and prairie dogs), ants, fishes, water erosion, chemical solution, wind action, physical and chemical segregation, glacial action, uprooted trees, and spring and gas vents. Campbell suspected the importance of burrowing mammals and ants, especially the latter, although he confessed his inability to understand their methods of operation.

In 1913, J. Harlan Bretz, of the University of Washington, published an article on glaciation of the Puget Sound region and therein described his careful studies of Mima Prairie.[9] He concluded that the mounds were probably the result of water and ice action. In retrospect, it seems logical that Bretz should have associated the mounds with glacial activity since the region under scrutiny, where the mounds are better developed than anywhere else in the United States, marks also the farthest point reached by the Vashon Glacier, last of the Western ice sheets.

Ellis and Lee, in 1919, laid the origin of the San Diego mounds to "the action of wind as it sweeps through the sparse desert vegetation and blows away the loose soil except where it is held by plant roots."[10] These investigators, like certain others before them, apparently did not realize that wind-built mounds are invariably *oriented* with the direction of the prevailing wind, whereas the mounds in question are either round or, if elongated, are aligned in no common direction.

The theory has been suggested, with variations, that the great power of freezing water has been instrumental in creating the mounds. The proponents of this theory may have studied the mound prairies of the

Courtesy of C. C. Nikiforoff

MIMA-TYPE MOUNDS IN THE "HOG-WALLOW" COUNTRY NEAR FRESNO, CALIF.

MIMA-TYPE MOUNDS ON LITTLE DRY CREEK, FRESNO COUNTY, CALIF.

BOULDERS DUG UP BY GOPHERS

THE LARGEST BOULDER HERE WEIGHS ABOUT TWENTY-FIVE POUNDS.

North, but surely not those of the warm coastal plains of southern California.[11]

In 1941, soil-scientist C. C. Nikiforoff published a long report on his studies of mounds in the Central Valley of California, principally in Tulare County.[12] The mounds here are so similar in shape, size, and arrangement to those of Puget Sound that certain photographs from the two areas appear to have been taken from the same station. In two respects, however, the regions are different: in Tulare County the mounds are underlain by a stiff clay hardpan and in the rainy season may be surrounded by water a foot or two deep, whereas in Puget Sound the mounds are underlain by coarse gravel and rarely, if ever, stand out as islands. Nikiforoff concluded that the "hog-wallow microrelief" was perhaps the result of ground-water pressure from the Sierra Nevada pushing up through countless "windows", now represented by mounds, in the hardpan of the valley.

A "MOUND ROOT"

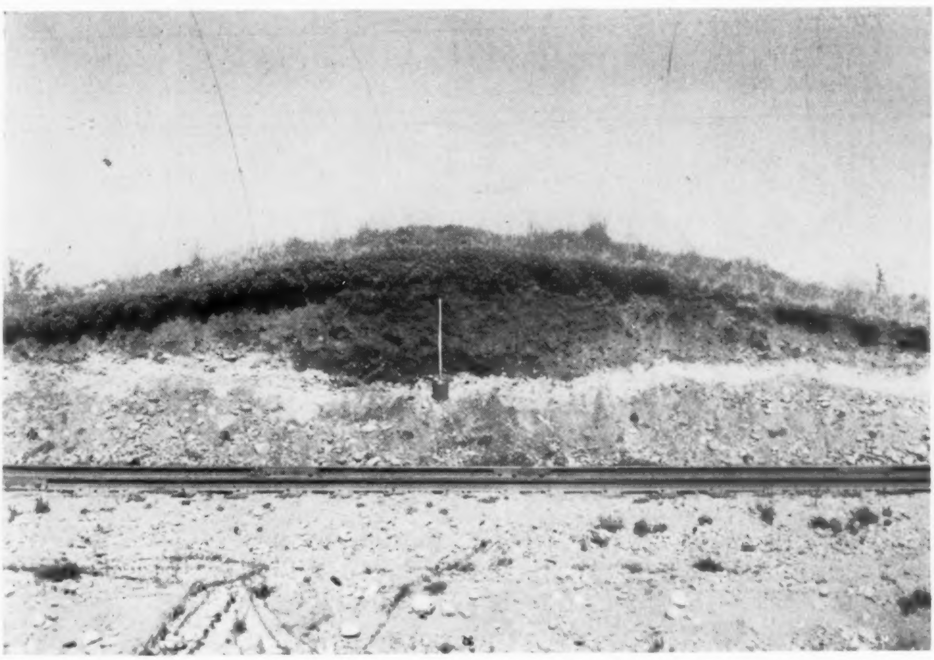
THE CAVITY IS FILLED WITH BLACK SILT.

The mounds in the Central Valley are so numerous, or were when the pioneer farmers arrived on the scene, that a special implement, the "Fresno Scraper," has been devised for the purpose of leveling them off and making the ground fit for cultivation. The machine is still widely used.

THE foregoing statements high-light the history of research on Mima-type mounds. In 1941, Walter W. Dalquest was engaged in a survey of the mammals of the state of Washington. As he extended his field observations to the prairies near Mima, he was at the same time enrolled in a course in glacial geology at the University of Washington. Here he learned that the origin of the prairie mounds was a mystery. About then the idea struck him that the mounds are the handiwork of pocket gophers over untold periods of time. When he broached the idea to old-timers born and raised on the prairies, they commonly put tongue in cheek and cautiously remarked, "W-e-e-l, they must have been pretty big gophers." This is a not illogical conclusion in view of the fact that the Mima Mounds are among the most spectacular—if not the largest—structures created by any mammal.

GOPHER POCKETS IN CHEEKS

The gopher of the Western states, *Thomomys,* is a ratlike, brownish rodent that burrows in the soil of prairies and mountain meadows and along stream channels in the



A MIMA MOUND SLICED OPEN BY A RAILROAD GRADE

SHOWING THE TYPICAL LENS-SHAPED BODY OF BLACK SILT RESTING ON A BED OF LIGHT-COLORED GRAVEL.

Courtesy of Solano Iron Works

THE FRESNO SCRAPER

FOR REMOVING MIMA-TYPE MOUNDS FROM THE CENTRAL VALLEY OF CALIFORNIA.

desert. It seldom ventures aboveground (as does the ground squirrel) and never enters the shade of the forest (as does the mole). It feeds on fleshy roots and often pulls an entire plant, root-first, into its subterranean chamber. The "pocket" part of the gopher's name refers to a deep, fur-lined pouch in each cheek. The pouch is about the size of an ordinary thimble and is used for carrying food, nesting material, and dirt. With this pouch to serve as a hod, with a pair of powerful forepaws for digging, and with the ability to run backward as well as forward in its burrow, the gopher is well equipped to excavate its labyrinthine tunnels.

Our theory of the origin of the Mima Mounds by gopher activity may be summed up as follows: A few tens of thousands of years ago, the Puget Sound prairie was laid down by rivers draining from the Vashon Ice Sheet. At first, the rivers were powerful and were able to carry the large boulders now found in the substratum of the prairie. Later, the rivers were quieter and were able to carry only the fine silt that, richened and darkened by the addition of grass-root humus, now composes the topsoil.

As soon as vegetation captured the raw new soil, we suppose that pocket gophers came in from the unglaciated country to the southward, advancing perhaps a few hundred feet in a gopher generation. By the

Courtesy of T. H. Scheffer

A GOPHER TUNNEL NEAR CORVALLIS, ORE.

THE EXCAVATION REVEALED THE NEST WITH FIVE NEWBORN YOUNG.

time they reached the southern end of Puget Sound they encountered a barrier, the evergreen forest that had been racing against them to occupy the new land. There they were stopped, and, to the present day, no gophers are found on the lowlands of the Pacific coast north of southern Puget Sound. To be specific, the northern limit of the gopher range is Point Defiance Park, in Tacoma.

We can picture then, thousands of years ago, gophers rooting through the thin silt of the Puget Sound outwash in search of plant roots. At certain places they dug deeply into the gravelly subsoil in order to make nest chambers well protected from prowling bear, wolf, or wildcat. Areal spacing of the nest chambers corresponded to the size of the "territory" of each animal. The center of an old territory now marks, we believe, the center of a modern mound.

In excavating for its nest chamber, the gopher was instinctively led to dig deep into the bedded gravel, regardless of the effort involved. When the animal ran into a large boulder it undermined the obstruction and allowed it to settle. Thus, we now find, at the base of most mounds, a concentration of

A POCKET GOPHER
A TAME ANIMAL (*Thomomys talpoides yelmensis*) FROM A PUGET SOUND PRAIRIE.

MIMA-TYPE MOUNDS ALONG A ROAD NEAR SAN DIEGO, CALIF.
DRAINAGE OF RAIN WATER IS SLOW BECAUSE OF A DENSE, UNDERLYING HARDPAN.

THE TAILINGS FROM A GOPHER MINE

A ROPELIKE MASS OF EARTH ON THE SURFACE OF A MOUNTAIN MEADOW IN EARLY SUMMER. A GOPHER DISPOSED OF WASTE CLODS BY PUSHING THEM INTO A SNOW TUNNEL. AFTER THE SNOW MELTED, THIS EARTHEN CAST WAS EXPOSED.

coarser materials. On the other hand, in foraging daily for food over its home range, the gopher was driven by less powerful instincts. When it encountered a bothersome rock in its path, it simply passed around it, shoving dirt along as it went. Thus, we find plainly exposed in the intermound hollows large boulders that were doubtless at one time buried in the topsoil.

Where the mound and its bed are in contact, there are found "mound roots," long a puzzle to geologists, which are simply abandoned gopher tunnels now filled with black silt contrasting in color with the yellow gravel around it. (They call to mind the peculiar devil's corkscrews, or *Daemonelices*, of the Nebraska sediments.[13] Once described as fossil plants or animals, the corkscrews are now generally believed to be the casts of burrows of extinct rodents.) We can imagine that, in cases where a gopher mound was abandoned by its owner for some reason or other, the nesting chamber collapsed and caused a depression at the crest of the mound, a characteristic feature of many of the mounds on Mima Prairie.

In fancy, it is easy to picture the start of a Mima Mound. It is less easy to account

GOPHER FOOD

FOOD STORE OF A GOPHER FROM TACOMA, WASH. THE STORE WAS ABOUT FOUR INCHES BELOW THE SURFACE OF THE GROUND. IT CONTAINED TWO QUARTS OF CUT RHIZOMES OF QUACK GRASS.

for its growth. For reasons that may never be known, the gophers carried more dirt toward the nest than away from it. Perhaps some biologist will suggest an experiment whereby the growth of a Mima-type mound can be studied from start to finish. At present, we do not know whether the mounds on the Puget Sound and other prairies are still growing, whether they are in equilibrium with the forces tending to reduce them, or whether they are shrinking.

In reviewing our evidence in support of the gopher-origin theory, we realize that most of it is indirect. We cannot say that we have seen a gopher, or a family of gophers, build a giant mound. Yet, as each new fact with regard to the mounds is uncovered, it seems to strengthen the gopher theory. And, what is perhaps more important, no countertheory based on the action of nonliving forces (such as wind and water) approaches a satisfactory explanation of the peculiar structure and arrangement of the mounds. The following facts have led us to our conclusions:

1. Mima-type mounds are distributed along the Pacific Coast exclusively in the range of the pocket gopher. On the north, both the mounds and the gophers terminate abruptly in the vicinity of Puget Sound.

2. Burrowing animals with habits similar to those of the gopher, namely, the ground squirrel (*Citellus*) and the mole (*Scapanus*), are known to occur on many of the mound prairies. We may deduce, however, that these animals are not pertinent to the formation of mounds since there are no ground squirrels in western Washington and no moles on most of the mound prairies of California.

3. Mima-type mounds are found only where there is a thin layer of workable soil on top of a dense substratum. It is significant that the substratum is of no particular geological formation. Thus near San Diego and Fresno, the substratum is a hardpan of cemented soil; a few miles southeast of Mount Hood, in Oregon, the substratum is basaltic rock; and in Puget Sound it is bedded gravel.

4. Where gophers are working in deep sandy soil unlimited by a basement they never form Mima-type mounds. In other words, their up-and-down movements are not restricted or localized. In deep soil near Olympia, Wash., only fifteen miles from the mound display at Mima, gophers have been working for untold years, and the surface of the ground is still so level that it is used as an airfield.

5. The usual agent in the formation of hillocks and mounds is geological deposition of one kind or another. This agent can hardly be responsible for mounds of the Mima type. Deposition, whether by ice, wind, or water, depends on a moving vehicle, and movement always results in a deposit which is aligned in one general direction. Mima-type mounds, as may be seen from aerial photographs, are unoriented. Also, deposition does not produce round mounds on a sloping terrain, as are occasionally seen on the gopher prairies.

6. For similar reasons, the agency of erosion may be dismissed. Erosion is generally the result of a moving vehicle. We may point out, further, that on the Puget Sound prairies, the mounds are draped the year around with a mossy turf that protects them from wind and rain-water erosion. And, in countless cases, the hollows between the mounds are completely closed depressions from which there is no rapid outflow of water—simply drainage through the porous gravel bed.

7. Only by a liberal use of the imagination can we conceive of a set of geological forces capable of producing the elaborate structure of the mounds, namely: the fluffy, unstratified soil of the mound adjoining a distinctly bedded substratum; the presence of "gopher-size" rocks in the mound as compared with the heavy cobbles beneath and beside the mound; the curious dip in the substrate beneath the mound; the mound roots; and the sunken depression usually found on the summit.

The reader may be disturbed to learn that *there are no gophers on Mima Prairie*, where climax examples of the mounds appear. This fact is of little importance, however, since there is clear evidence that gophers once lived there. Through some unknown agency—fire, flood, or pestilence—they were wiped out. Once gone from the prairie, they would not return, for the prairie is now isolated from surrounding gopher range by a river and a forest. Since the Mima Prairie Mounds are identical in structure with others only a mile away where gophers *are* found at the present time, we feel confident in stating that both series of mounds are of common origin. And, as we have pointed out, Mima Prairie is only one among scores of plains along the coast where Mima-type mounds occur.

Finally, we should like to pose three questions, the answers to which some enterprising naturalist may be led to seek:

First, what are the dynamics of mound formation? Were the present mounds built in a matter of years? Centuries? Do conditions of the environment favor their growth at the present time?

Second, does ground water at certain times of the year and in certain localities act in the same way that a soil hardpan does, to force the gophers into mound-building activity?

Third, how widespread in North America are gopher mounds of the Mima type? Shortly before his death in 1942, government naturalist Vernon Bailey told us that he had puzzled over Mima Prairie for years and wondered whether some giant gopher might have lived there long ago. He also said that in his extensive travels he had seen similar formations in southwestern South Dakota, southwestern Louisiana, eastern Texas, and many other parts of the West. Only in California, Oregon, and Washington have we had an opportunity to study them.

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INCREASE IN DUES FOR 1948

By action of the Executive Committee annual dues to the A.A.A.S. will be increased from \$5.00 to \$6.50, effective October 1, 1947, and applying to the journals to be delivered during 1948. If a member wishes to receive both *Science* and The Scientific Monthly, the charge will be \$10.00. Non-member subscriptions to *Science* and The Scientific Monthly will be \$7.50 per year each, plus, in the case of *Science*, foreign postage (outside the Pan-American Union, \$1.00; Canada, 50 cents.) Rates for The Scientific Monthly for periods of less than one year will be computed at 75 cents per month.

TOWARD A SCIENCE OF HOUSING

By C. THEODORE LARSON

Mr. Larson (M. Arch., Harvard Graduate School of Design, 1929) has been architect and project planner for the U. S. Housing Authority, technical editor of Architectural Forum, *architect with the N.H.A., and technical consultant for the Kilgore Subcommittee on War Mobilization, Military Affairs Committee (1944–45). Since March 1947 he has been with General Homes, Inc., Columbus, Ohio.*

THE age of synthetics has given us unlimited freedom in design—instead of having to shape our dwellings to meet the limitations of materials as made by nature, we can now tailor them to conform with whatever patterns of family and community living we find most desirable. Walls need no longer be inert masses of masonry with no function other than to hold up the roof and provide shelter against a harsh external environment. They can be made to do extraordinary things—radiate warmth or coolness, glow with soft light, move about, perform household chores, ward off or destroy harmful organisms, otherwise serve man's bidding. The design objective becomes *control* of environment—the development of new forms that will promote man's health and comfort, increase his productive capacities, and enable him to develop physically and culturally beyond any standards of perfection he has ever dared set for himself in the past.

Such is the promise. But, between this bright new architecture and what actually exists, there is an enormous gap. The closing of this gap calls for further scientific and technological progress.

The problem. Our housing supply is notoriously deficient. Since 1900 the output of new houses has not been large enough to keep up with the increase in families. As a result, the nation's housing has deteriorated progressively—we have not been able to build new houses as fast as existing units were wearing out. The 34,854,532 dwellings in the United States, according to the housing census of 1940, had a median age of over twenty-five years; surprisingly large percentages lacked running water, private baths, flush toilets, electricity, and refrigeration; 14 out of every 100 needed major repairs before they could be called safe for human occupancy. Slums and congestion and blight have been steadily spreading like an insidious disease. Now, as an aftermath of war, the accumulated shortage of dwellings is revealed in its full enormity. So great is the need that even if the building industry attains and holds a production volume of 1,250,000 units a year for 10 years, we shall still be nearly 4,000,000 units short of the total the National Housing Agency estimates as necessary to take care of anticipated population increases and to replace existing dwellings which fail to meet even the lowest standards of health and decency.

This housing deficit is directly attributable to the fact that the housebuilding industry has fallen behind technologically. Methods and materials used centuries ago are still in use. Houses built in such fashion are too costly for the average citizen's pocketbook; year by year they have been getting more rather than less expensive. Output consequently has been low. In 1925, the highest peak year on record, only 937,000 new dwellings were built, and in 1933, a depression year, production sank to a low of 93,000 units. Despite an unprecedented number of construction starts last year, completions have lagged and home building again is at a virtual standstill. In short, the industry has been steadily pricing

itself out of the market. Only the wealthy are able to afford new houses; other families must double up and triple up in obsolete hand-me-downs.

High labor rates, high material prices, and high charges for financing are usually blamed for the high costs of housing, but, even if these were lowered (as they have been in instances), houses built along traditional lines would still be excessively expensive because of the industry's inherent inefficiencies. Too much time is required to produce such houses—and time is costly.

The conventional house is an assembly of many small bits and pieces—approximately 30,000 different kinds—all of which are individually fabricated in various plants and must be delivered to a particular site and laboriously fitted together into a complete structure. An ordinary wall is built up in a dozen or more layers in a complicated composite of paint, siding, kraft paper, sheathing, nails, screws, studding, insulation, lath, plaster, paste, and wallpaper or their equivalents. Usually, to produce such a house, some 4,500 to 5,000 man-hours of labor are required. Roughly two-thirds of this time is spent in processing and shipping the elaborate array of materials to a building site, the other third in putting them together as a structure.

As a general rule, site work can proceed only when the weather is favorable. Long delays occur if there are wet spells or freezing. Construction workers consequently have had to be paid high hourly wages in order to hold them in the building trades. Even so, because so much time is lost on the job, their total annual wages have generally been lower than those in the mass-production industries. They have seldom been able to afford the products they themselves have helped produce. Like other homeseekers with limited incomes, they have had to be content with secondhand dwellings.

Here clearly is an important area for technical research and development. Home building must be freed from its traditional dependence on weather. At the same time techniques must be developed that will step up the productivity of the individual construction worker so that the unit costs of housing can be lowered without cutting established wage rates and the purchasing power of potential customers. With year-round production and a guarantee of a substantially higher annual income, there should be little reluctance on labor's part to accept more efficient modes of construction.

New production approaches. The problem of a backward building industry has been recognized for a long time. During the 1930's numerous house producers saw the importance of not being tied to the weather and began to do something. By transferring as many site operations as possible to a central plant (in some cases simply a large tent on the building site), these pioneers in house prefabrication made it possible for their mechanics to work indoors continuously, rain or shine. In the process they also cut the 1,500 to 1,800 man-hours usually required for outdoor site-erection work down to 300 man-hours, or even less. Such time reductions, however, were obtained chiefly by increasing the amount of work done in the factory. The average net over-all saving in man-hours has been only about 8 percent, according to a comparative study of prefabricated and conventional war-housing projects undertaken by the Bureau of Labor Statistics at the request of the National Housing Agency. As the war-housing experience also shows, greater economies can be obtained through large-scale operations directly on the site: when several hundred dwellings are built at a time, the flow of work can be so organized that construction time per unit is cut almost in half, with a corresponding saving in site labor costs.

Because the house prefabricators have not been able to cut costs substantially, their output has been relatively low. Last year,

according to the Office of the Housing Expediter, some 37,200 units were produced by 198 companies—an average of 180 units for each producer. This can hardly be called mass production.

Obviously, it is not enough merely to move indoors the usual sawing and hammering together of small bits and pieces. More advanced techniques of fabrication are needed to take advantage of the shift to the factory and to get the full economies implied by industrialization. The production of a house must be viewed as a single integrated process that extends all the way back to the original sources of supply—the forest, the mine, the quarry, and the farm. If this is done, then large abbreviations of time can be made at every step where there is any handling or processing of materials. All such time savings should be directly translatable into dollar savings for the housing consumer.

The necessity of this more fundamental approach to the problem of cost reduction has become increasingly evident as the nation's housing need has grown more acute. Thus, paradoxically, while the government's program of housing for veterans has been bogging down because of the inability of conventional builders to produce at reasonable prices, there has also been notable progress toward a higher level of industrial efficiency in home-building.

Numerous new producers are tooling up to enter the housing field. To a large extent these producers come from the aircraft industry and other war-expanded industries which have facilities that can be readily adapted to the manufacture of low-cost houses. Unlike the earlier house prefabricators whose units have differed little from the conventional house in design or construction, these newcomers are experimenting with new materials, new designs, and wholly new systems of house fabrication.

The Harmon Corporation, for example, has developed a steel panel house which it expects soon to produce at the rate of 1,000 units a month at its converted shipyard plant at Wilmington, Del. Another typical new producer is the Butler Manufacturing Company, Kansas City, Mo., which has utilized its experience in fabricating metal grain bins and store fronts to develop an attractive aluminum panel house. Reliance Homes, Inc., of Philadelphia, has been experimenting with a house which can be made in either steel or aluminum sections measuring up to 8 by 25 feet; these sections will be nested together on truck trailers, transported to the site, and rapidly put in place by cranes.

Porcelain enamel likewise is acquiring a new prominence in house building. The Lustron Corporation, a subsidiary of Chicago Vitreous Enamel Products Company, is planning to turn out 15,000 houses a year utilizing a system of ceramic-surfaced steel panels. Bathtubs and other fixtures are easily shaped out of the wall material and made an integral part of the structural shell. Andrew Higgins, the New Orleans shipbuilder, has been experimenting with a similar structural system. Large prefabricated wall panels, with doors and windows incorporated, are delivered to the site and butted end to end; then, after pipes and wiring have been run through the hollow insides, a "foamed" concrete mixture is pumped into the panels. This forms, in effect, a 2-inch monolithic concrete wall faced inside and out with steel sheets prefinished in any desired color. To mothers with small children the ceramic wall surfaces offer a special attraction; a damp cloth readily removes any smudges or hand prints.

These new producers look upon themselves as housing manufacturers. Already, even before most have completed their tooling and gotten into full stride, they have set up their own trade association. They shun the term "prefabrication." Instead, they talk about "industrialized houses" and the implications of using new structural materials.

Creation of materials. Logically, there should be a single material versatile enough in itself to do everything that the present multiple wall and roof materials are required to do. As stated by the National Housing Agency in an analysis of housing costs issued shortly before the war ended:

> If a building material could be developed which would permit the economical molding by mass-production methods of monolithic self-supporting wall panels, containing all the characteristics which are essential in the exterior and interior walls of a house, as well as self-supporting roof and floor panels, a very important step would have been taken toward solving the problem of excessive housing costs.

Such a single, multipurpose material, it was hinted, should be able to cut the cost of the house shell at least in half. The net effect would be to reduce the total capital cost of house and land by approximately 30 percent.

Significantly, much of the current experimentation in building materials points in this direction. An outstanding example is the aluminum-faced, plastic, honeycomb-paper core panel being developed by Lincoln Industries, of Marion, Va., in collaboration with the Forest Products Laboratory. This material is a direct outgrowth of the plastic fiberglas radomes (radar equipment enclosures) developed for use on Navy planes during the war. Paper sheets are run through alternating glue-strip rollers, stacked, and gang-sawed into slices 2 to 4 inches thick. Each slice is then pulled out, like an old-fashioned paper Christmas bell, to form a honeycomb core, which is impregnated with a plastic resin and sandwiched between thin sheets, or "skins," of aluminum. The resulting panel is lighter than cork, has surprising strength, and can be made in large, easily handled sizes. Units snap-lock together on the site to form finished walls and roofs. The whole process can be mechanized. Even in the laboratory stage, only two weeks are required from the time the paper and aluminum sheets are fed in at one end of the production line until a house is ready to move into. Three airplane companies—Douglas, Consolidated Vultee, and Goodyear—have been building experimental houses using the Lincoln material and a similar material produced by the U. S. Plywood Corporation. Their production plans, however, are still indefinite.

An engineering firm in Cleveland—the H. H. Ferguson Company—has been sponsoring experiments with a panel system which uses sheets of corrugated paper glued together and then impregnated with various plastic resins. The type of resin used determines the structural behavior; panels can be varied in toughness and strength, as well as being made fireproof, waterproof, and verminproof. For extra strength plies can be folded together to form reinforcing ribs of variable depth and spacing. At present the plastic-paper panels are used only in making cargo containers and movie sets, but it is expected that their use will be extended eventually to low-cost houses.

Cotton also offers long-range possibilities as a building material, although currently its cost is too high. During the war experimental samples were produced by the War Production Board's Office of Production Research and Development showing that it is technically possible to float cotton fibers into thin films of plastic and then to laminate these sheets into a hardboard that can be pressed into any desired structural shape. Such cotton-reinforced plastic material, if it can be produced cheaply, would be in demand for the manufacture of sinks and bathtubs as well as for structural panels, and the cotton-growing South would play an important role in the development of the industrialized house.

Wood likewise presents a fertile field for research. When a tree is cut up into ordinary lumber, at least 75 percent is lost in stumpage, lopped-off branches, discarded bark, shavings, and sawdust. This fact has stirred

numerous experimenters to create new type wallboards by mixing sawmill sweepings with cement, plastic resins, or other binders (even lime and skim milk have been tried). The most promising avenue of attack appears to be to reduce wood to its basic elements—cellulose and lignin—and then to use or recombine these elements in various ways with other basic materials.

In the case of concrete, there is considerable current experimentation with new lightweight aggregates—vermiculite, perlite, pumice, tufa, "bloating" clays, and even organic substances like straw, palmetto, and cottonwood fibers. Precast concrete panels made from such aggregates are said to have better insulation and greater resistance to moisture penetration than the older, denser types. In addition, they have the industrial advantage of weighing considerably less—an important consideration when it is remembered that the conventional house weighs 30 to 50 tons and requires excessive brute labor merely for its handling during construction.

The N.H.A. goal of a single, multipurpose building material may not be far distant. As these examples show, the paths of research cut across each other: the new synthetics are essentially alike in that they are all capable of being varied in form and substance to meet different conditions. What the ideal synthetic will be—whether it should be made from things that are grown or things that are mined or quarried—is mainly a question of research and economics. Possibly the answer lies in the field of low-pressure plastics. In any event, there is evidence of a great ferment of activity directed toward the creation of new-type building materials.

Evolution of standards. The legislation under which the government has been extending market guarantees and other financial assistance stipulates that every new type of house or material must be tested for sound quality. Since N.H.A. has no testing facilities of its own, it has had to rely on public and private testing laboratories for such work. Besides the National Bureau of Standards and the Forest Products Laboratory, the principal testing facilities include the U. S. Public Health Service, the Bureau of Reclamation, and the Bureau of Entomology and Plant Quarantine. Also active is the Engineering Research Station at Pennsylvania State College, which boasts a "climatometer" built originally with W.P.B. funds to test military equipment under varying climatic conditions.

As this network of testing laboratories has discovered, it is not always an easy task to measure the adequacy of structural innovations. Steel and aluminum houses present special problems of heat flow and moisture condensation. Some of the structural systems employ such novel engineering principles that values cannot be readily computed, nor do loading and racking tests developed for conventional construction always provide a sufficient index of actual strength. The durability of new materials is another big question mark. Various accelerated aging tests have been devised which put materials through severe temperature and humidity changes, but although any substance that survives such testing can be considered durable enough for housing use, there is as yet no precise correlation between the length of the test cycles and the actual life expectancy of the material.

A prerequisite to developing more advanced techniques of testing is knowing exactly what to test for. Unfortunately, the only standards we have are the specifications that have evolved out of many years of practical experience with conventional building materials. Once established, they are difficult to change. And, because house construction has been largely a local activity, each locality has its own accumulation of such standards—there are, it is estimated, some 2,000 different local building codes in

the United States. Each of these codes represents a separate hurdle to the producer who wants to market factory-built houses on a nation-wide basis.

Attempts are being made to break this impasse and to set up new criteria. Before the war the National Bureau of Standards, the Forest Products Laboratory, and the various government agencies concerned with housing prepared a set of minimum structural requirements, which was recommended for use by local authorities in modernizing their building codes. Recently the N.H.A. has sponsored a revised edition of this publication. The document is an important step toward the formulation of a uniform national code for house construction, but the burden of proof is still put on those who propose to build unconventionally to show that their proposals will provide adequate safety and quality. In short, there is as yet no fully satisfactory guide for the development and evaluation of factory-built houses using new-type materials.

The lack of desirable performance standards should not be construed to mean that the new factory-built houses are substandard. They are, in fact, distinctly superior to the average conventional house in quality and livability. The difficulty is one of requiring compliance with standards that have become obsolete and consequently wasteful. Many local codes, for instance, specify that house walls must be at least 11 inches thick, even though the structural loads can be handled easily enough by walls only 2 or 3 inches thick when new materials are used. Some localities actually have banned the use of metal walls.

In the past, high factors of safety—three to ten times the calculated loads—have also governed house construction. This was necessary because the materials used—wood, stone, and the like—had to be accepted pretty much as formed by nature. A high allowance for variation in performance was a guarantee that the structure would stand up intact against earthquakes, hurricanes, heavy snowfalls, and other extraordinary happenings. With the introduction of new synthetic materials whose uniformity and quality can be rigorously controlled through inspection in the factory, the need for such large factors of safety disappears. Airplanes are built with factors of safety as low as 1.5 and are well able to withstand even more extreme hazards than are encountered by the average house.

Theoretically, the new structural systems can be engineered to meet any desired range of performance requirements. To make them conform to the standards established for conventional construction is to make a Procrustean demand. Ceilings, for example, are usually required to be so constructed that under maximum loading they will not deflect more than 1/360 of the room span. The reason is that beyond this bending limit plaster is likely to crack, and ceilings usually have been made of plaster. However, if the ceiling happens to be an aluminum skin, it can flex sharply under load and still be able to snap back into its original position without being any the worse. To keep the panel from exceeding the traditional deflection limit, the metal skins would have to be increased in thickness or other structural design changes made, which would increase the cost. New deflection limits are needed, but what these limits should be—1/270 or 1/240 or something less—remains a moot question.

In setting up desirable standards of performance, the task essentially is to predetermine the range of functions a house should serve and then to prescribe the necessary behavior as a control over the development of new materials and structural systems. Findings from many lines of research must be brought together and coordinated. This is in itself a research task of unlimited scope, for the performance standards will constantly change as new advances in science and technology open up new potentials.

The shape of things. Just as the first automobiles were "horseless carriages" (even to the extent of having whipsockets) and the first airplanes looked more like kites than "flying machines," it is not surprising that the factory-built houses coming on the market are quite conventional in appearance. Similarly, it is safe to predict that these houses will soon evolve into forms more consistent with the needs of contemporary living and reflecting the greater freedom in design that comes through industrialization.

Some experimental models already show architectural advances. Materials like porcelain enamel encourage the use of soft color combinations, which make the houses pleasantly attractive to the eye. By using flat instead of pitched roofs, producers also are discovering that substantial savings (up to $500 a unit) can be gained. At the same time, by recessing the walls or projecting the eaves to form sheltering overhangs and porches, a more distinctive and livable type of dwelling is obtained.

Unquestionably, the most advanced design developed so far for industrial production is the Dymaxion House, a round, igloo-like structure of aluminum and plexiglas suspended from a central mast and anchored to concrete footings. The circular plan offers the advantage of a maximum of space being enclosed with a minimum of materials, while the tensional construction uses the metal at its strongest capacity. Light in weight (only 3 tons), the house is divided into rooms of variable size by means of large, standardized utility units, which serve also as storage, kitchen, bathroom, and laundry equipment compartments. Each bedroom has its own bath with fixtures stamped integrally out of the partition walls. Anyone who has inspected the full-size prototype in the Beech Aircraft plant at Wichita, Kan., will testify that the curving walls, the ribbon fenestration, and the high room ceilings give a luxurious sense of interior space. Tooling up costs are high for Fuller Houses, however, and little progress has been made since more than a year ago when the experimental house was first publicized. Recent reports indicate that the company is getting new financing and expects to be in production this year.

Another unusual house design is the dressed-up Quonset hut which the Great Lakes Steel Corporation of Detroit has developed in response to requests from ex-G.I.'s who became familiar with its virtues while overseas. In its new de luxe form the Quonset is considerably modified: the familiar half-barrel shape is retained, but side walls are hung perpendicularly from the supporting arches, and end walls are recessed to form porches or glassed-in living rooms. Special windows, flower boxes and trellises, overhangs for walkways and carports, built-in wall cabinets, and other details provide architectural variety.

Exactly what the manufactured house of the future will look like is still a matter of conjecture. In line with Louis Sullivan's precept that "form follows function," Frank Lloyd Wright, Gropius, Neutra, Kiesler, and other pioneering designers here and abroad have been experimenting with new ways of enveloping space. The forms vary widely—they range from rigid geometrical combinations, using the square or the hexagon or some other element as the module of design, to completely amorphous units in which walls curve continuously and indoor space fuses with the outdoors almost indistinguishably.

Some designers have suggested that the house should be split up into separate "space units" for each of the various household activities. These units could then be manufactured individually and hooked up together on the site with "connector units" to form individual dwellings of variable design. Paul Nelson, for example, has developed a "suspended house" scheme, which consists of tall metal columns supporting roof trusses from which walls of glass or plastic,

adjustably transparent or opaque, are suspended; within this large, boxlike shell, essentially a general living room, are a variety of irregularly shaped room units, each an independent structure designed to conform to the requirements of a particular activity (e.g., food preparation, sleeping, bathing, study) but all linked together by spiraling ramps and terraces suspended at different levels. New room units could be added or substituted as desired. The entire structure would provide a three-dimensional, easily alterable flow of family activity.

Underlying all such innovations is the need for more precise information on exactly what are the desirable patterns of family activity. It should be the objective of a comprehensive program of housing research to provide such information. Many elusive factors must be ferreted out and studied, including the subconscious dwelling needs of people, and the psychological effects of color and of various geometrical forms when used as space enclosures for the human organism.

Community development. The more the new dwellings depart from traditional forms, the more imperative it becomes that they be put up in planned groupings rather than as isolated units. No matter how pleasing an individual Dymaxion or Quonset or X-space house may be by itself, it would be jarringly conspicuous if placed in a setting of conventionally designed houses. To show off to best advantage, the new models should be surrounded by others of the same type.

Besides esthetics, straight business reasons call for the organization of dwellings into well-planned neighborhoods or communities. The economies of mass production in the factory must be matched by the savings which come from large-scale operations on the site. Unlike automobiles, radios, refrigerators, and other manufactured goods, the factory-built house is not ready for immediate use when it leaves the plant. It is simply, to use a term already adopted by the emerging new industry, a "package" of prefabricated parts or components that must be put together into a structure and tied to a foundation on a particular area of the earth's surface. Before this structure becomes fully livable, it must in turn be hooked up with various transportation and communication networks, power lines, utilities, and local services. Unless the house manufacturer is willing to do all this site work himself, he must sell his "package" to others who will. This presents a special problem, for the traditional marketing system is geared to serving small local builders who put up only a few houses at a time, usually on scattered individual city lots. Most of the new producers are therefore seeking to sell direct to large-scale builders instead of through the customary channel of distributors, dealers, contractors, and subcontractors, each of whom has to add a sizable profit as compensation for his middlemanning. Buying in quantity, the big builders should be able to pass the economies of factory production straight on to the housing consumer and, at the same time, through efficient site work, add new savings of their own.

To the housing designer, this trend toward mass marketing of houses has important implications. As the government discovered during the war, good housing comprises much more than just houses. When schools, stores, or recreational facilities were lacking, or when too much time was required for workers to travel to their places of employment, housing projects were slow to fill up and sometimes even stood empty despite the congestion of population in war-production centers. The N.H.A. planners had to consider the addition of community services and amenities.

At least one new producer—General Homes, Inc., of Columbus, Ohio—has recognized this basic principle and plans to produce complete community projects as its end product. Not only will it fabricate the

parts for individual structures (using a system of aluminum-surfaced panels with insulated aluminum cores), but it will also acquire land, develop it, and erect the houses, a hundred or more at a time, together with shopping centers, nurseries, parks, playgrounds, and other desirable neighborhood adjuncts. The CIO, which has long been urging this sort of industrial development, is forming mutual home-ownership corporations and housing cooperatives, made up largely of union members, to buy the projects upon completion. The company expects to fabricate and build 1,700 aluminum houses this year and 10,000 or more in 1948.

When housing is viewed as an integral part of the problem of planning neighborhoods and communities, it becomes clear that individual dwellings should be designed to conform with the most desirable patterns of community activity as well as individual family activity. What these larger patterns should be—the interrelationship between the house and other structures in the community—is a matter that likewise calls for scientific investigation. We have as yet very little coordinated information to serve as standards of performance in community development.

Our cities and towns have grown by stretching haphazardly out into the countryside, leaving the older central areas to wither and rot. The gridiron streets and blocks, originally intended for horse-and-buggy transportation, have been long outmoded. Only with great difficulty and at large cost have a few new auto highways been superimposed to relieve the traffic bottlenecks. The airplane brings new planning difficulties before the older ones have been solved; time saved in flying across country is lost in going from the local airport to the office or home. Further anachronisms are bound to arise when people begin traveling in rockets at supersonic speeds.

This implies a program of housing research on the broadest possible social scale. Changing needs in other fields of human activity—communication, education, recreation, health, sanitation, power, manufacturing, farming, business, finance, and so on —should likewise be studied to determine the effects they will have on the functional requirements of the house and the community. The lengthening of the educational cycle to include very small children at one end and older adults at the other, for instance, raises the question of how far these new needs should be provided for in the home and how far in other community structures.

One of the most pressing problems is the question of health raised by current happenings in the housing field itself. Approximately 35 percent of the houses now being built in this country are going up on outlying land beyond the reach of municipal water-supply and sewage-disposal systems. This percentage is expected to double within the next year as builders find it increasingly difficult to obtain suitable land at reasonable prices inside the city limits and are forced to go farther and farther out. In doing so, they must rely largely on cesspools and septic tanks. Fortunately, the N.H.A. is aware of the sanitation hazards and, in collaboration with the U. S. Public Health Service, has launched a research and testing project aimed at improving the design of individual sewage-disposal systems.

It should be noted that our use of water as a carrier of household and industrial wastes is very wasteful. Not only is there the problem of pollution, which makes it necessary for the next community downstream to purify the water for drinking purposes before it in turn adds new pollution, but the present per capita consumption of water is excessively high (about 30 gallons daily, of which only 1 gallon is used internally). If our sanitary equipment were more efficiently designed, the average American home could get all the water it needed by merely con-

densing it out of the atmosphere as part of the air-conditioning system. To this end Buckminster Fuller, the Dymaxion designer, has proposed the use of water-saving "fog guns" for bathing and dishwashing, and the elimination of sewage by electronic heating, which would evaporate the liquids and leave a dry, easily removable ash. A utility-service unit combining equipment of this sort with an individual low-cost power plant would make the house mechanically independent of the city. Dwellings could be placed wherever desired.

Sanitation is only one of many health factors that must be considered by the housing designer, however. The house must be made as hazardproof as possible. Even more important, it must be designed to be an instrument in promoting good health, mental as wel as physical. As a guide in such work, the American Public Health Association's Committee on the Hygiene of Housing has undertaken to set up standards of healthful housing; a report analyzing desirable features in the neighborhood environment of dwellings is now in preparation and will be published soon.

Similar broad approaches to the problems of housing and community development should be made from other directions. Any contradictions or conflicts in the standards set up by specialists in the various fields would immediately indicate the need for further specialized research. Properly coordinated, the program of housing research would be self-generating.

Expanding horizons. The outward push of our cities, long evident and now accelerating in a potentially enormous burst of housebuilding, presents sharply the question of what should be done with the obsolete central areas. Urban blight is certain to widen and intensify as people move into new homes in the satellite communities springing up on the outskirts. The older developments cannot be left to become ghost towns.

This problem has already come to the attention of the nation's lawmakers. The Taft-Ellender-Wagner general housing bill provides that the Federal government shall extend substantial financial aid to localities for the acquisition and redevelopment of blighted areas. Obsolete structures would be demolished, new street patterns laid out, and the land made available for parks, playgrounds, airports, housing projects, business buildings, factories, or other new uses. Unless adequate planning safeguards are set up, however, the new construction is likely to fall again into eventual blight and decay, so that the expensive cycle of acquisition and redevelopment will once more have to be repeated. It is the responsibility of a properly planned program of housing research, as a service to future generations of taxpayers, to see that this does not happen.

The issue is not centralization versus decentralization, but rather mobility versus stagnation. Traditionally, we have insisted on a fixed pattern of growth for each locality —like Major L'Enfant's famous "plan," which has crystallized into the traffic-snarled congestion of downtown Washington, or Ebenezer Howard's dream of self-sufficient "garden cities," which has been translated into a Letchworth or Welwyn existing only by virtue of its economic dependence on metropolitan London. As instruments of social growth, communities are constantly being changed in size and character by the very advances which they themselves help to create. Ever-changing, expendable, even ephemeral in instances, each must develop according to a variable rather than a fixed pattern of growth. Furthermore, each must be looked on not as an isolated local phenomenon but as an integral part of a region-wide, nation-wide, even world-wide mosaic of continuous change.

This concept of planning means that the development of any form—from the simplest tool to the most complex metropolis—cannot be considered complete until it has

been eliminated in favor of more desirable forms. The objective is increasing productivity—the continuous development of new forms which can be used as specific means for specific needs. But, unless there is a tie between the elimination phase and the research phase, there will not be a harmonious continuity of development. The obsolete must be removed to make way for the new. A system of time-zoning is needed to ensure the orderly elimination of obsolete structures.

In short, an increasing number of persons and things and ideas must be brought into working unity on the problems of research in the housing field. The facilities for such cooperation are still largely lacking, however. A few educational institutions—Purdue, Harvard, the University of Illinois, the University of Michigan, and the Bemis Foundation at M. I. T., for example—are doing notable research in housing, but this work has been on an insufficient scale and without benefit of a central plan. As Senator O'Mahoney's Temporary National Economic Committee found after extensive hearings in 1940, there should be an agency within the government, similar to the National Advisory Committee for Aeronautics, with ample funds to sponsor a coordinated program of technical research in housing on a scale broad enough to meet the nation's needs. A bill authorizing the N.H.A. to assume this responsibility was introduced two years ago by Senator Kilgore and Senator Wagner. Its provisions have been absorbed into the general housing bill recently before Congress. To combine the broader social approaches with such technical research in housing and community development should, of course, be among the functions of a National Science Foundation.

With proper organization for research, the horizons are indeed unlimited. Man has already come a long way as a designer of environment. From the poor harried troglodyte who could do little more than kindle a fire and pile up some rocks outside his cave as a barricade against other marauding animals, he has advanced to the point where he has the potentials and resources to fashion any kind of habitat he may desire. He has penetrated the stratosphere and is thinking about traveling through outer space. He communicates instantaneously around the world. He watches events while they are happening far over the horizon. He has even produced power as great as the sun's. Deftly he manipulates the invisible, the inaudible, the intangible.

Man's further development depends on his increasing his control of environment—physically, economically, culturally. With such control, an increasing surplus of human energy can be released from the restrictive forces of an uncontrolled environment. This surplus—leisure—becomes available for the creation of even more desirable forms, an infinite variety of forms that man can use for his own good. It is an exciting thought that man, as an evolving form of life, has only to determine, before proceeding to produce, the kinds of environment he needs to promote and guide his own evolution.

THE ROLE OF CONVENTION BUREAUS IN A.A.A.S. MEETINGS

THE BOSTON CONVENTION BUREAU AND THE 1946 MEETING

By JAMES A. MORRISON

Manager, Convention Bureau, Boston Chamber of Commerce

THERE are 44 cities in the United States that maintain convention bureaus either as individual civic agencies or as departments of local chambers of commerce. These bureaus have annual operating budgets ranging from $15,000 to $100,000 a year, depending on the size of the city and its importance in the convention field. The funds subscribed to maintain convention bureaus come principally from obvious sources, such as hotels, restaurants, retailers, utilities, taxicab companies, purveyors, and suppliers.

In normal times keen competition exists among the principal cities of the United States for the convention visitor's dollar. We want and need conventions in Boston because they bring some seven to eight million dollars in new money into the area each year—money that has been earned in other cities and states.

One month after our Convention Bureau in Boston was reopened in November 1945, it came to our attention through the local press that the A.A.A.S. would hold its first postwar convention in St. Louis March 27–30, 1946. Upon reading this announcement, I pulled out our file on the A.A.A.S. and found that twelve years had elapsed since the Association had last met in Boston, December 27–30, 1933. Because of this long interval, the probability that an east-coast meeting would follow a midwest meeting, and the fact that James B. Conant, of Harvard, was the 1946 President, we felt we had a very strong case to present in behalf of Boston.

In order for Boston to be officially considered by the A.A.A.S., the first and most important job of the Boston Convention Bureau was to secure the active support and endorsement of a Boston convention bid by the nine member-institutions of higher learning in this city.

Our first step was to write to the presidents of the nine local universities, which are as follows:

Boston College
Boston University
Harvard University
Massachusetts Institute of Technology
Northeastern University
Radcliffe
Simmons College
Tufts College
Wellesley

The college presidents unanimously endorsed our proposal to bring the 1946 December meeting to Boston, and as a result an official convention invitation committee was set up with one representative from each of the nine schools.

Under the direction of this special committee, the Convention Bureau then prepared a personal leather-bound brochure of invitations to the Executive Committee of the A.A.A.S. containing official letters of invitation from the Governor, the Mayor, the presidents of the nine local universities, local scientific organizations, and the commercial interests such as the Chamber of Commerce and the hotel association. This brochure gave to the Executive Committee full assurance that Boston would heartily welcome the scientists' convention and would meet every requirement, including

meeting halls for 60 simultaneous sessions, an exhibit hall for the Scientific Exhibition, and some 4,000 hotel rooms. Many hours of detailed effort went into the preparation of these personalized invitations.

The decision on the location of the December 1946 convention was to be made in St. Louis by the Executive Committee. It was necessary for the Convention Bureau Manager to attend the Executive Committee meeting in St. Louis to present personally Boston's bid. The decision of the committee was unanimous for Boston, although many of the members could recall their last visit here in 1933 when the city experienced one of the worst blizzards in its history, with temperatures at twenty below zero. Fortunately, those memories of Boston weather did not affect the final decision.

With Boston now definitely set as the place for the 1946 Annual Meeting of the A.A.A.S., the work of the Convention Bureau was actually in its initial stages. Our first job was to poll the 41 hotels in the city to secure a blanket reservation for all their transient hotel rooms for the dates of December 26–31, 1946, in the name of the A.A.A.S. At the same time it was necessary to secure some 60 meeting rooms in hotels and in clubs, churches, and schools that were conveniently located to the hotels in which the delegates would be staying. I know of no convention that places a heavier demand for meeting space on a city than the "four-ring circus" of the A.A.A.S. In Boston 35 of the meeting rooms were located in our local hotels; the remainder were placed in university buildings and private institutions.

From the first of October until the date of the meeting, our office served as a housing bureau for the convention. Over 3,400 requests for hotel reservations were handled by a staff of secretaries. Each reservation required at least two letters, one to the visitor and one to the hotel. Allocating hotel accommodations for three to four thousand people is a man-sized job.

Of course, throughout the year it was necessary for the Bureau Manager to attend many of the meetings of the local Committee on Arrangements. Among the obligations the host city must assume is the raising of an entertainment fund of some $3,000 by this Committee on Arrangements. In Boston this fund was subscribed largely by the local universities, with some assistance from commercial laboratories and industries. Harvard University provided special entertainment for the visitors, including a concert by the Harvard Glee Club. The Entertainment Committee also secured some 2,000 tickets for a concert of the Boston Symphony Orchestra. These were distributed without charge to our visitors.

When the meeting was about to open, it became the responsibility of the Convention Bureau to register the visitors. This required a staff of 14 girls for three days, 18 typewriters, and an elaborate Kardex filing system so that one could locate in Boston any one of the registrants.

The week between Christmas and the New Year is normally the point of lowest occupancy for local hotels. Traveling men have all gone home for the Christmas holidays. The dates of the annual convention of the A.A.A.S. therefore come at an ideal time, providing capacity business for hotels and restaurants at a period that would otherwise be the poorest week of the year. A detailed survey showed that in excess of $60 per person was spent by each out-of-town visitor to the A.A.A.S. Convention—a quarter-of-a-million-dollar plum for Boston. In addition to the monetary value of the Meeting, it draws more national publicity than any other convention in the United States. The convention was on the front page of the *New York Times* each day with a Boston date line; *Time* and *Newsweek* each ran a full page. There were some 78 science writers from newspapers throughout the country who personally covered the Boston meeting.

In conclusion, it is important to emphasize the need for carefully examining the facilities available for the A.A.A.S. in future convention cities. In my opinion there are not more than six or eight of the larger cities in the country that can properly accommodate this large gathering of scientists. To avoid conflicts with meeting dates of other educational associations that hold their conventions during Christmas week, we who are Managers of the Convention Bureaus would like to see your Association set up a long-range program of meeting locations for at least five years ahead. Certainly the schools, colleges, and business interests of Boston would be glad to welcome the return of your Association at the very first opportunity.

NOTES ON THE CHICAGO MEETING, A.A.A.S.

(*Continued from page viii*)

(L) ***History and Philosophy of Science*** sessions will include a symposium on "The Foundations of Modern Physics" Saturday morning, December 27, and, in the afternoon, a discussion of the "Problems of Concept Formation in Psychology." A Sunday afternoon session on social concepts has been arranged.

(M) *Engineering*. Section M will meet Tuesday, December 30, at the Sherman Hotel, with the *Limnological Society of America*, to discuss "Limnological Aspects of Water Supply and Waste disposal." Theodore A. Olson, School of Public Health, University of Minnesota, will be chairman of this meeting. Section M will also meet on Monday, December 29, to discuss topics of general interest.

The American Society for Horticultural Science will hold sessions in the Palmer House each morning from December 29 through December 31 for the reading of papers on pomology, floriculture, and vegetable crops. On Monday afternoon, December 29, there will be a joint meeting with the *American Society of Plant Physiologists* at which a symposium on "Dormancy in Plants" will be presented. J. P. Bennett will be chairman. In the evening there will be three round-table discussions: "Methods of Breeding Horticultural Crops," G. M. Darrow, chairman; "Mineral Deficiency Diagnosis," D. Boynton, chairman; and "Methods in Extension Work." Tuesday afternoon the Section on *Agriculture* (O) will meet with the Society to discuss "Breeding Horticultural Crops." W. S. Alderman will be chairman. The Annual Banquet of the Society will be held Tuesday evening. On Wednesday morning, December 31, there will be a joint session of the Society and the ***Potato Association of America***, at which papers on pomology and floriculture will be read. The annual business meeting will be Wednesday afternoon.

The ***American Society of Parasitologists*** will hold six sessions (all morning or afternoon meetings) December 29–31. No joint sessions with other societies have been planned.

The American Society of Zoologists will hold its Annual Meeting in Chicago December 29–31. On each morning there will be general sessions for the reading of papers. The afternoons of December 29 and 31 will be devoted to symposia sponsored jointly with several other biological societies. On Tuesday afternoon, December 30, there will be a demonstration program at the laboratories on the campus of The University of Chicago. At the Zoologists' Dinner to be held in the Blackstone Hotel on December 30, Dr. Franz Schrader, vice-president of the Section on *Zoological Sciences* (F), will speak on "Three Quarter-Centuries of Cytology."

The Botanical Society of America is planning twenty-four sessions for December 26–30. General botany, physiology, microbiology, phytopathology, mycology, taxonomy, morphology, and plant anatomy will be discussed in various meetings with associated societies such as the *American Society of Plant Physiologists*, *American Society of Plant Taxonomists*, *Mycological Society of America*, *The American Phytopathological Society*, ***Ecological Society of America***, and the *American Society of Naturalists*.

CHILD LABOR OF THE TERMITE SOCIETY VERSUS ADULT LABOR OF THE ANT SOCIETY*

By CLARENCE HAMILTON KENNEDY

Dr. Kennedy (Ph.D., Cornell, 1919) has had a long and distinguished career in zoology and entomology. He has been at Ohio State since 1919 and has been Professor of Entomology there since 1933. Although the essential literature on the social insects is widely scattered, we were forced by limitations of space to omit the careful bibliography prepared by Dr. Kennedy.

IN COMPARING the pattern of termite social organization and behavior with the very different behavior and social organization of ants, we find almost at once that the termite society is operated on child labor, whereas the ant society is operated on adult labor. Students of the societies of insects, which form of life has arisen independently many times, as evidenced in the termites, beetles, ants, bees, and wasps, point out that the society of the termites is weak and continuously on the defensive, whereas that of most ants is vigorous and continuously on the offensive. Termite literature abounds with the opinion that ants are the termites' worst enemies. There are reasons why.

Limited by space and the reader's time, this discussion will cover only three of the more than a dozen species of Reticulitermes distributed in the Orient, about the Mediterranean, and across the United States. These of the family Rhinotermitidae have the pattern of organization and behavior of the higher termites but lack the high specializations of the tropical Termitidae. In ants, more diverse forms will be considered. I have made no original study of termites but I have been much interested in them in comparison with the organization and behavior of ants, which societies I have studied many summers. The present knowledge of American termites is based on the studies of Nathan Banks, T. E. Snyder, A. E. Emerson, S. F. Light, and A. L. Pickens.

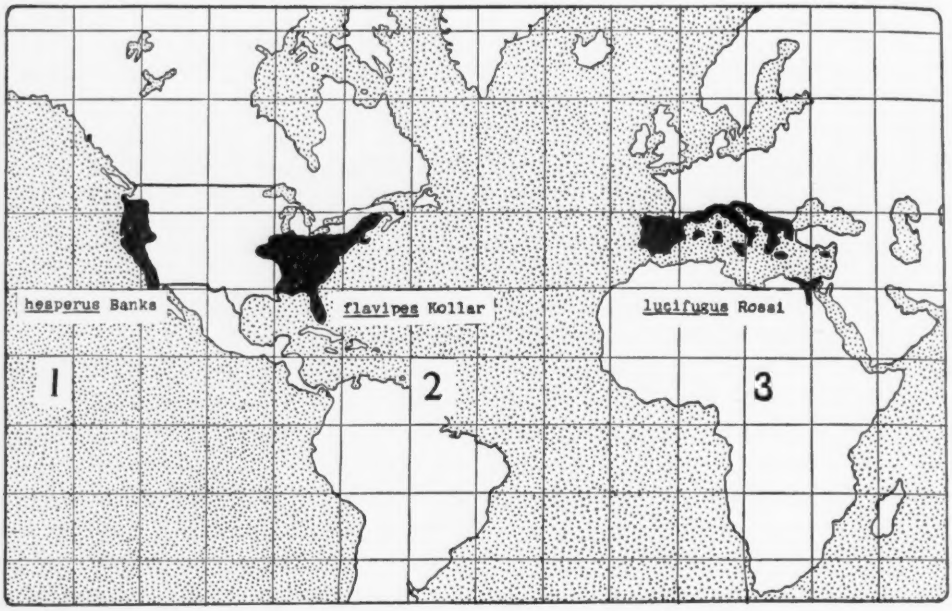
Fortunately for our knowledge of termites, the distribution of some of our most destructive forms of Reticulitermes, in the North Temperate Zone, coincides rather exactly with the greatest density of zoologists and entomologists. Such seldom have to go much farther than their own woodsheds and garages to locate laboratory material. In Europe there is one species, *lucifugus* (Figs. 1–3). In America there are about a dozen species. Two, *flavipes*, of the Eastern states, studied by Banks, Snyder, and Emerson, and *hesperus*, of the West Coast, studied by Light and Pickens, are the better-known forms. Their habits are so similar we will not distinguish between the two.

Reticulitermes rates as a subterranean,

* This article was presented December 26, 1946, as a lecture before the Cambridge Entomological Club as part of the Christmas A.A.A.S. program.

This comparison and concept was worked out, and part of the figures were drawn, at the University of Michigan Biological Laboratory, Douglas Lake, where the author was registered as an "Investigator" (of ants) in the summer of 1946. It was completed at Ohio State University.

It was initiated as a review of the present knowledge of instars and castes in termites and ants. The study shifted to the relationship of these to social physiology, which soon became the problem of immaturity in the termite society versus maturity in the ant society. Only casual references to this difference were found in Wheeler's writings. Dr. Theodor Just suggested that Wasmann had published on such a point of view. This was finally located (Wasmann, Erich. Die Democratie in den Staaten der Ameisen und der Termiten, Bd. X, *Forsuchungen zur Völkerpsychologie und Soziologie,* 1931, 309–336). His discussion is from the point of view of polymorphism, a factor not introduced in the present article. The best review of polymorphism is in Wheeler, Wm. M. *The Social Insects*, 1928, (VII, VIII), with full references to 1928.



FIGS. 1–3. DISTRIBUTION OF THREE SPECIES OF RETICULITERMES

AMONG THE MOST DESTRUCTIVE OF TERMITES, THESE SPECIES HAVE BEEN STUDIED MORE THAN OTHERS.

or ground, termite. It has to have contact with damp soil to obtain moisture. If this contact is maintained, the colony can then burrow into aboveground wooden structures. Reticulitermes eats wood. Figures 4–6, from S. F. Light, show a nest in the framework of a dwelling where the colony may have entered through the exploratory tunnel at the lower left or from the infected stump at the lower right. The latter connection has a covered way (Fig. 6) over the concrete foundation.

Softer parts of the wood are eaten first, but finally all parts are destroyed except the walls of the nest. Always the nest is completely invested with an antproof outer wall, which is usually of the original wood; at times it is built of a cement of soil, frass, excrement, and salivary secretions. This wall is opened only at tunnel heads when the galleries are extended and once or twice a year for the emergence of the adult winged males and queens. The simple-minded worker termites survive in a vicious world by shutting themselves away from the overpowering problems that would arise if they had to struggle with the external environment. Like children in human society, they live in the house. They are without the adult vigor of structure and behavior that would save them in the outer world.

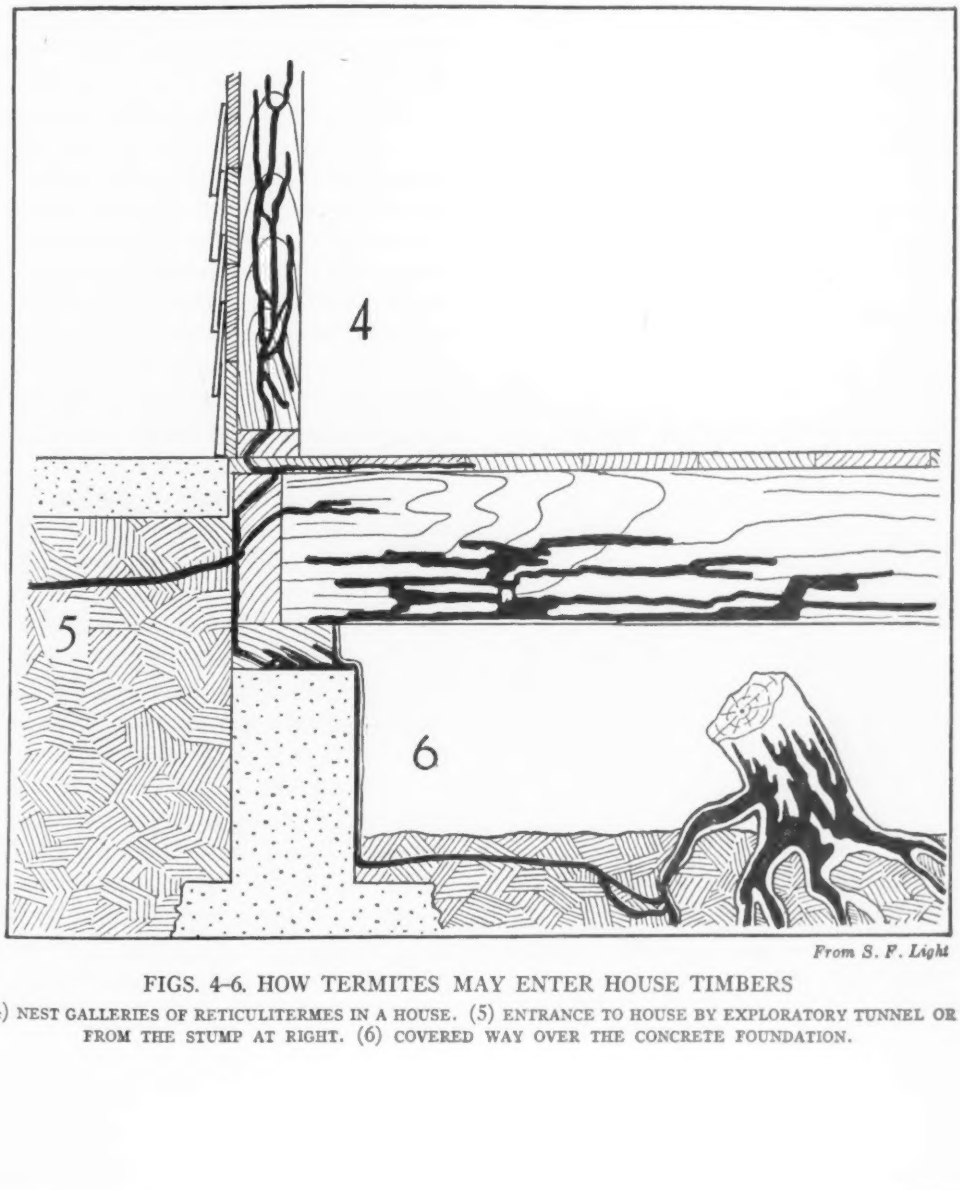
Wood, which termites cannot digest, is also their food. The intestine of the young of all castes, and of the workers throughout life, is packed like a sausage with large flagellate protozoa (Figs. 7–12), which are of special flagellate families that apparently have evolved in the termites and in some roaches. The protozoa digest the wood, and the termite host absorbs the products of digestion. A termite in excellent health will carry his own weight of protozoa.

Protozoa are thus an essential part of termite social economy. The active young termite just hatched is without them, though it can eat regurgitated, or stomodeal, food from the mouth provided by the older young and the workers. In its second instar it is fed proctodeal food from the anus of the workers, which liquid contains the living protozoa necessary to the termite's well-being. These protozoa multiply with great

rapidity and soon pack the young termite's intestine. The process of infection has to be repeated after each ecdysis, or shedding of the exoskeleton, at which time the protozoa are evacuated.

Because of their great, toothless jaws, mature soldier termites cannot chew wood. They are fed by mouth on stomodeal food regurgitated by young termites and workers, which have wood-chewing jaws with teeth. The same is true for the matures of the three reproductive classes, which have good jaws but degenerate jaw muscles. Thus, in later life, when fully developed, the soldiers and reproductive castes have to be fed by the young and workers, so that they get along with few or no protozoa. The flight queen is limited to a few protozoa since she cannot carry many and be light enough for easy flight; but she has to carry a few to infect her first young.

The food habits of Reticulitermes offhand appear very simple as the society is established in a home of indefinite extent, which at first is also a mass of food. They eat their own wooden house but because they, like all other animals, require proteins, carbohydrates, fats, various salts, and vitamins, an exclusive wood diet is an incomplete diet (Fig. 13).

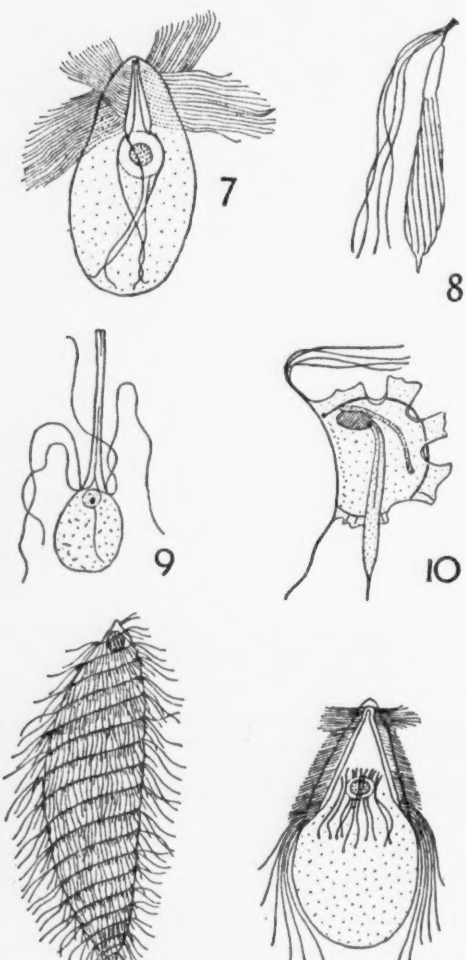


From S. F. Light

FIGS. 4–6. HOW TERMITES MAY ENTER HOUSE TIMBERS

(4) NEST GALLERIES OF RETICULITERMES IN A HOUSE. (5) ENTRANCE TO HOUSE BY EXPLORATORY TUNNEL OR FROM THE STUMP AT RIGHT. (6) COVERED WAY OVER THE CONCRETE FOUNDATION.

The matter of carbohydrates is solved through the transformation of the cellulose content of wood into usable sugars by the protozoan fauna of the termite intestine. It does not appear to be known whether the protozoan is "diabetic" and after digesting wood within its body excretes sugars into the termite gut, or whether the digestion of wood may be external to the protozoan by



From Harold Kirby Jr.

FIGS. 7-12. PROTOZOA FROM TERMITES

THE FOLLOWING FLAGELLATES ARE EXAMPLES OF PROTOZOA THAT LIVE IN THE ALIMENTARY TRACT OF TERMITES AND DIGEST THE WOOD (CELLULOSE) CONSUMED BY THESE INSECTS: (7) STAUROJOENIA, (8) STREBLOMASTIX, (9) OXYMONAS, (10) TRICHOMONAS, (11) HOLOMASTIGOTES, (12) TRICHONYMPHA.

enzymes secreted by it into the sawdust-filled termite intestine. Fragments of evidence suggest both forms of wood digestion, and evidence points to an abundance of this type of food.

Theoretically, the problem of fats appears simple and follows on the abundance of carbohydrates. Nearly all young insects and young mature female insects, as is shown by the presence of fat bodies, must elaborate fats easily. This fact of a youthful digestion in a land of wood and sugars might well be why, in the termites, evolution appears to have favored immature forms for the bulk of the societies' household labor. Such physiological advantages and also limits are not directly visible, but we know they direct or limit evolution as vigorously as do structural elements.

The great problem in termite nutrition is that of a supply of nitrogen to build amino acids, which build proteins, which build protoplasm in its many body forms. The animal is a protoplasmic energy-transforming mechanism. Nitrogen is a must. One suggestion is that wood harbors much fungus mycelium, so that proteins may be derived from such fungus sources. This surmise is strengthened by the ease with which many of the higher tropical Termitidae have shifted to fungus for their major food supply.

A second possible source is the fixation of nitrogen from the air by some of the various bacteria that are associated with the protozoa in the intestine, but research has not identified such bacteria.

A third source may be the protozoan bodies evacuated from the young termite at the end of each growth stage. These are shown to be eaten by friends as part of the termite's general fecal diet. All feces are eaten and re-eaten, perhaps for traces of protein. A known source of protein by social conservation rather than from sources extraneous to the society is tapped by the habit of eating all corpses. None is wasted. In human society the habit of eating human flesh, not uncommon among savages, is gen-

erally classed as primitive and is associated with an immature stage in social evolution. Such reasoning tends to class termites as immatures.

Another habit of various social insects is similar and, while broadly a conservation of protein, is also a resource in any food shortage. It is the consumption of their own eggs and infants. In termites the conditions that produce infanticide are not known, but shortage of proteins appears more probable than one of wood. With babies, termites toss in the cripples and the ill, which are usually eaten a bite at a time as they drag about the colony. This again is an undifferentiated or immature type of behavior.

The practice of cannibalistic infanticide in termites, ants, and some semisocial Coleoptera appears to support Wheeler's theory that trophallaxis, or the exchange of regurgitated food and various secretions between mother or nurse and young, is the binding force in the insect nursery. Whatever the social binding force may be, it is obvious that it does not stand the heavy social strains of selfish individualism, because termites eventually eat one another. This circumstance suggests that it is not psychic, as in the vertebrate family and society. In the vertebrate nursery household difficulties usually tend to intensify mother love and the related psychic bonds that hold mother or nurse to the young. The vertebrate mother tends to defend the lives of her young even to her own death. Trophallaxis never exhibits the social binding force characteristic of the psychic mechanisms of the large vertebrate brain.

Snyder's observations on the annual flight of the winged royalty suggest another source of reserve protein. In Reticulitermes at the time of the great annual flight of winged first-form reproductives, that of the royal kings and queens, there is also produced a secondary swarm of second-form reproductives, those with wing pads only. These have served as child labor, then have evacuated their protozoa to become reproductives, social liabilities, as they have to be fed by the laboring classes. At the time of the great flight they disappear as suddenly as they have appeared. They may each, with a male attendant and loyal workers, have dug away from the home nest to establish new nests without ever having had a nuptial flight. If so, evidence of such new nests in numbers about the home nest has not been found. A few remain in the home nest and are responsible for the great populations of mature colonies. But the majority are merely excess royalty. Our own suggestion is that their plump, royal bodies may provide protein at an annual feast of the laboring classes.

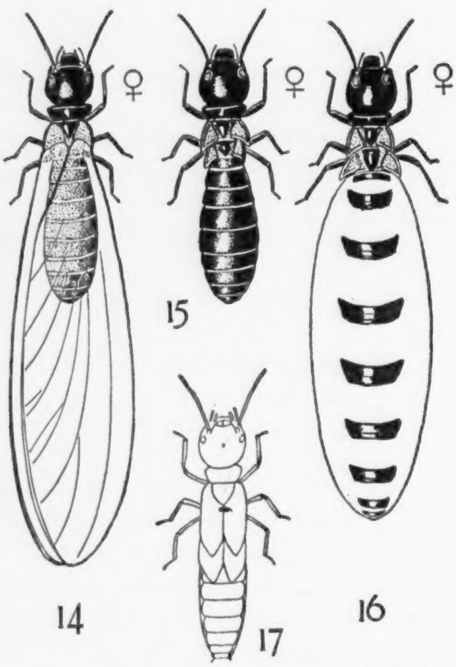
Food Used by Termites

1. *Carbohydrates:* from wood.
   Cellulose converted to sugars by intestinal Protozoa.
2. *Fats:* from sugars, and
   from fatty exudates lapped from body surface of friends.
3. *Proteins:*
   Original: From fungus mycelium?
   From intestinal nitrifying bacteria?
   From protozoan bodies?
   Conserved: By eating the dead and injured.
   By eating eggs and young in emergency.
   2nd and 3rd form queens eaten?
   By proctodeal food containing dead Protozoa.
   By eating feces containing dead Protozoa.
   By a nitrogen cycle: Malpighian urates used by intestinal Protozoa and these by the termites.
4. *Stomodeal food:* Predigested food from the mouth. Probably mostly sugars but with other elements.

FIG. 13. TERMITE FOODS

Leach and Granovsky have suggested a nitrogen-conserving cycle by which the nitrates from the termite are discharged into the protozoan-filled intestine directly from the Malpighian tubules. The nitrates would be used by the protozoa, which would then be eaten by friends in their general fecal diet. The regular use of a fecal diet strongly suggests that it contains nitrogen and perhaps vitamins.

The present positive knowledge of the domestic economy of termite society is, as you have read, a wonderful tissue of intriguing assumptions. This knowledge has but few data that are positive enough to be cheering, such as wood for daily meals, with cannibalism, infanticide, and a side diet of fecal matter. Eating is at the low level of an internment camp where adult, restrained table behavior completely disappears. It is childish behavior at its lowest. In a world of skilled adult socii Emily Post would disapprove of nearly every move a worker termite might make. All would be beneath her mature, adult dignity.



Redrawn from papers by Snyder

FIGS. 14–17. THE TERMITE QUEEN

(14) VIRGIN ROYAL, OR WINGED, QUEEN. (15) SAME WITH WINGS SHED. (16) SAME AFTER SOME YEARS; ABDOMEN ENLARGED WITH EGGS AND FAT. (17) LAST, OR SIXTH, NYMPHAL STAGE OF A ROYAL WINGED QUEEN. THE ROYAL MALES ARE SIMILAR TO THE ROYAL QUEENS (FIGS. 14, 15, AND 17) EXCEPT FOR MINUTE DIFFERENCES AT TIP OF ABDOMEN. WITH AGE THE MALE IS MUCH AS IN FIGURE 15 BUT IS THINNER IN THE ABDOMEN AND BECOMES HUMPBACKED.

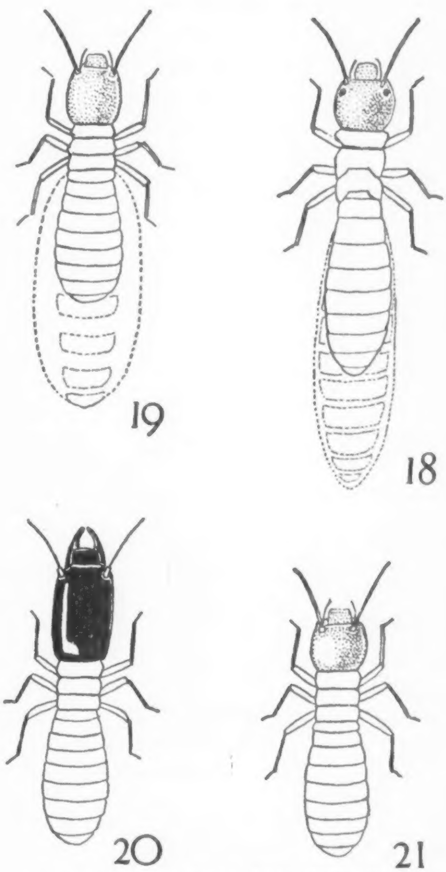
In a nest of Reticulitermes, if lucky, we might find five castes—workers, soldiers, winged royalty, and two grades, or castes, of complemental royalty, one with wing pads and one little different from workers, as its members have not even wing pads. The vast population of tens of thousands in a large nest will be pale-white workers, shown in Figure 21 at the lower right corner. These are of two sexes but are sterile. All castes have equal numbers of both sexes, with the possible exception of the two castes of complemental reproductives, which are usually polygamous; sometimes a dozen or more queens live with one male. About every tenth individual in the scurrying hordes will be a large-headed, long-jawed soldier (Fig. 20). The other five items are queens; reading from the left, Figures 14–16 are of a virgin winged queen of the last, or adult, instar. The black queen is the same with her wings broken off after mating. The very large wingless queen, third from the left, Figure 16, is again the same royal queen after several years, when her abdomen has enlarged with fat and eggs. Not shown is the winged male, which resembles the winged queen and which, later, without wings, resembles the young queen (Fig. 15). No change in his size takes place with age, though as he grows older he becomes humpbacked. Figure 17 is a last-stage nymph of a winged queen or king.

The queen (Fig. 18) at the upper right is a second-form reproductive, recognizable by the short wing pads. After she has mated with a similar or other form of male, her abdomen finally enlarges, as is indicated by the dotted lines. Snyder thinks that queens

of this second reproductive caste carry the main burden of egg production in mature colonies. He has found that a second reproductive form in a few weeks will produce as many eggs as the royal winged queen during her first year. But it must be remembered that during the first year in a royal nest, which, with king, queen, and half a dozen workers, is still a family rather than a teeming society, all developmental processes are at a low energy level without the stimuli of the later great mobs of individuals. Apparently the second-form reproductives boost the population hurriedly when times are good.

The queens of worker form (Fig. 19), without wing pads occur in some nests. Less is known about their age in number of instars, their position and function in the society. They would appear to be one instar below those queens with wing pads. However, termite specialists determine maturity in all three forms of queens by the loss of the two minute anal stylets, a loss which marks sexual maturity in the winged royal queens. The number of instars for reproductives is stated variously as from seven to ten.

Compare the winged queen (Fig. 14) with that with wing pads (Fig. 18), with that without wing pads (Fig. 19), and finally with the worker at the lower right (Fig. 21). Structurally, excepting the loss of stylets, the second and third queen types resemble the worker more closely than they resemble the winged queen. They are wingless and resemble immature forms. Their habits are household habits. They do not face the external environment except for a short time at the annual flight, when some of them come out and try to fly. Contrasted with these who face the environment on wings, they have the fear of it characteristic of all immature forms of the colony. In spite of reproduction they have the behavior of the immature. Present evidence has not yet given fully confirmed data that the wingless reproductives are at full growth in some lower instar than that of the royal pair. Their general body structure suggests fewer instars. They are immature or childish in major characters of structure and are immature in their household behavior. (See Thompson, 1916, and Thompson and Snyder, 1919 and 1920.)

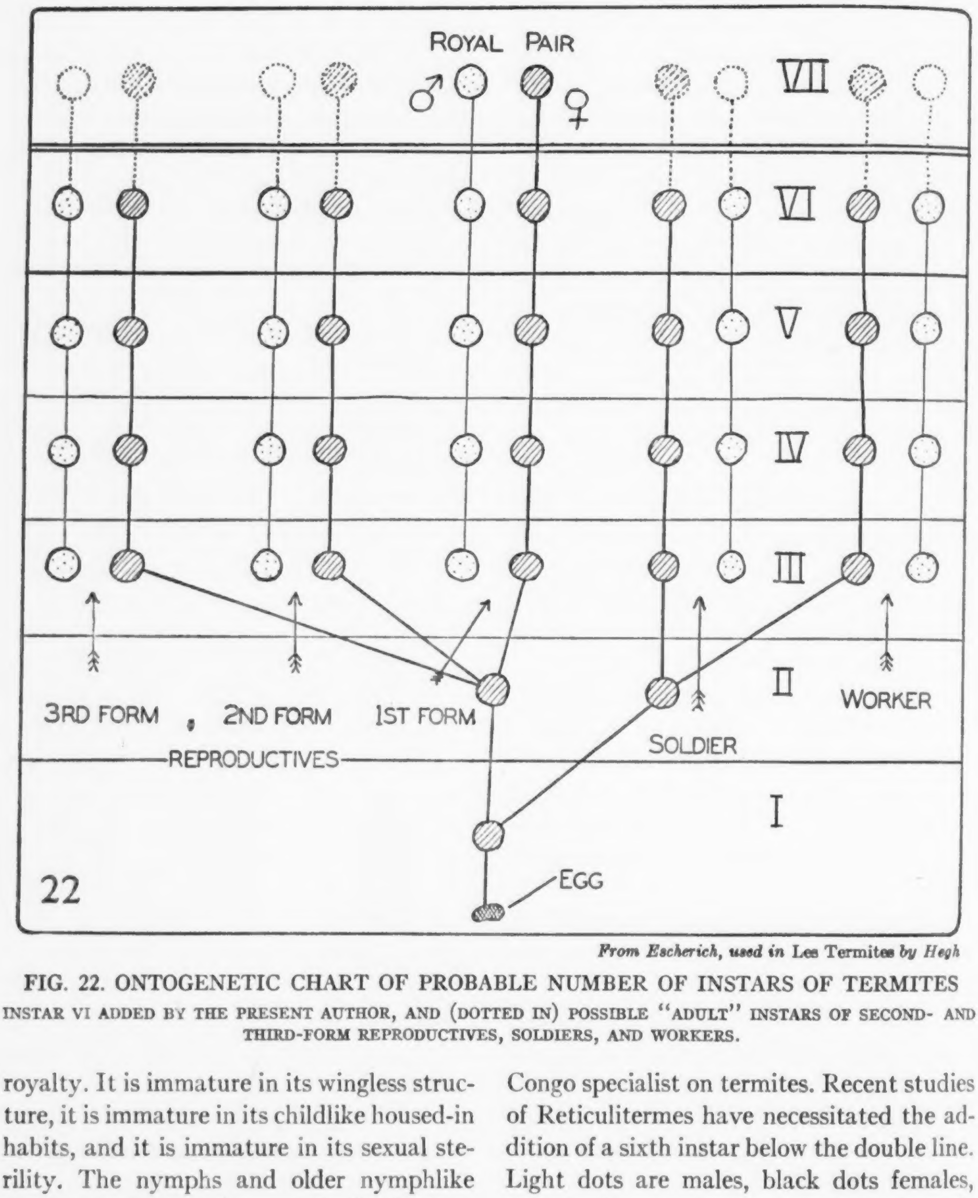


From papers by Snyder, Light, Kofoid, Pickens

FIGS. 18–21. VARIOUS FORMS OF TERMITES

(18) SECOND FORM OF QUEEN WITH PARTIALLY DEVELOPED WING PADS; SECOND-FORM MALE IS SIMILAR. (19) THIRD FORM OF QUEEN WITHOUT WING PADS AND WITH THE APPEARANCE OF A WORKER; THIRD-FORM MALE IS SIMILAR. DOTTED CONTOURS SHOW ABDOMEN OF THE QUEENS WITH ADVANCING AGE (CF. FIG. 16). (20) SOLDIER. (21) WORKER, WHICH IN ALL INSTARS IS NYMPHAL IN STRUCTURE.

The worker is immature in so many structural and physiological characters that we can term it an immature even if it passes through as many instars as the winged



From Escherich, used in Les Termites *by Hegh*

FIG. 22. ONTOGENETIC CHART OF PROBABLE NUMBER OF INSTARS OF TERMITES
INSTAR VI ADDED BY THE PRESENT AUTHOR, AND (DOTTED IN) POSSIBLE "ADULT" INSTARS OF SECOND- AND THIRD-FORM REPRODUCTIVES, SOLDIERS, AND WORKERS.

royalty. It is immature in its wingless structure, it is immature in its childlike housed-in habits, and it is immature in its sexual sterility. The nymphs and older nymphlike workers constitute the great bulk, the tens of thousands, of the colony. There are ten to each soldier and thousands to each reproductive. They give the broad, nymphal picture of the colony's nymphal structure and nymphal behavior.

Some of these points of life history are shown in a widely used chart (Fig. 22) first drawn by Escherich on data from Grassi, the great Italian zoologist, and reproduced here from *Les Termites* by Hegh, the Belgian Congo specialist on termites. Recent studies of Reticulitermes have necessitated the addition of a sixth instar below the double line. Light dots are males, black dots females, since both occur in equal numbers in each caste column. Some of Snyder's data suggest that all castes have an equal number of instars, but other observations by the same author indicate extra skins, shed with little change of form, after the sixth instar. Pickens has suspected that small soldiers in young colonies may be mature in the fifth instar. Thus a suspicion is creeping into discussions that the number of skins shed during growth may vary at times. Evidence is

accumulating to indicate that the number of instars may vary in individuals in other of the more primitive orders of insects.

All first-instar nymphs appear alike, and the same is true for the second instar. During the latter stage the young are fed proctodeal food and become infected with protozoa. Among nymphs of the third instar a skilled specialist can recognize those that will become soldiers. In winged royalty, wing pads appear at the sixth instar (Fig. 17), and apparently all queens become recognizable by plumper bodies than those of workers and by a lighter color, owing to a change to stomodeal food away from the earlier dark, wood diet. The protozoan fauna is greatly reduced, and the anal stylets are lost. This loss of stylets suggests that the second reproductives (with wing pads) and the third reproductives (without pads) at sexual maturity may be in the same instar of development as that of the mature winged royal queens, which are rated variously as in the seventh to tenth instar.

The termite colony is a society built on, and made possible by, incomplete metamorphosis. In insects with incomplete metamorphosis the young are active from the time they hatch from the egg (Fig. 23). Each hustles its own living. The mayflies, dragonflies, roaches, grasshoppers, the hemipteroid bugs, and various relatives all work from babyhood. They face a hostile world, however, and take on a defensive and, in carnivorous forms, an aggressive behavior, almost that of an adult in many respects. The termite society, on the other hand, has shut itself within its antproof walls where all vestiges of an aggressive behavior pitted against a hostile world have been reduced

Child Labor in a Termite Society

(Assuming a life of 7 instars in all castes)

	Instars of nymph 1 2 3 4 5 6	Instar of adult 7	
Queen........	Work-work-work-work.....	Rears 1st brood.............	15 years?
Male.........	Work-work-work-work.....	Digs nest...................	15 years?
2nd queen....	Work-work-work-work.....	....	years?
3rd queen....	Work-work-work-work.....	....	years?
Soldier (1)....	Work-work-work-work-work	work-work-work...........	2–5 years?
Workers (10).	Work-work-work-work-work	work-work-work............	2–5 years?
..	Work-work-work-work-work	work-work-work-work-work	
..	Work-work-work-work-work	work-work-work-work-work	
..	Work-work-work-work-work	work-work-work-work-work	
	Immature nymphs-work	*Immature "adults"*-work-work	
..	Work-work-work-work-work	work-work-work-work-work	
..	Work-work-work-work-work	work-work-work-work-work	
..	Work-work-work-work-work	work-work-work-work-work	
..	Work-work-work-work-work	work-work-work-work-work	
..	Work-work-work-work-work	work-work-work-work-work	

Original

FIG. 23. CASTES OF TERMITES

CHART SHOWING THE IMMATURE WORKERS OF ALL CASTES OF RETICULITERMES AT LEFT OF VERTICAL LINE AND THE "ADULT" INSTAR OF WORKER, IMMATURE IN STRUCTURE AND BEHAVIOR, AND SOLDIER CASTES AT RIGHT OF VERTICAL LINE. TEN WORKERS AND ONE SOLDIER ARE SHOWN.

to the lowest terms. With termite behavior stricken of aggressive individualism, we are tempted to think of it in its various aspects as almost a baby behavior.

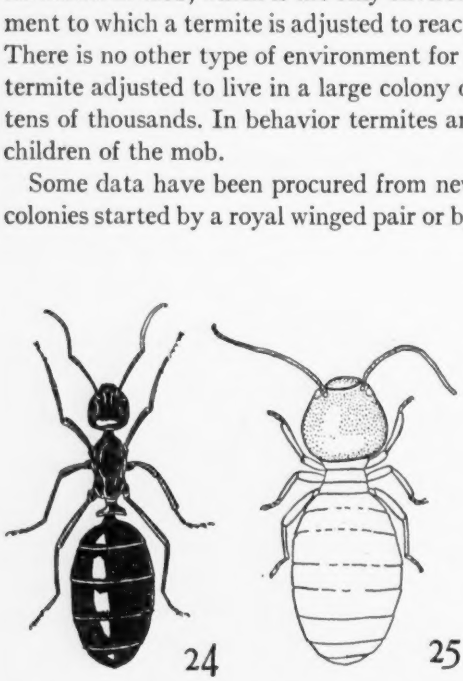
The other bit of evidence that points to a society built on the labor of immatures is that of the great difficulty found by students of termites in rearing observation colonies. Light started a hundred and lost all within a year. Only one or two investigators appear to have certainly reared individual termites of Reticulitermes stage by stage from egg to old age. The difficulty appears to be that termites are so highly social and so delicately adjusted to the enclosed, purely social environment that the investigator cannot set up any similar environment for a few individuals that he can mark, count, and watch. He has not been able with the best insectary methods to devise an artificial, environmental crowd or mob, which is the only environment to which a termite is adjusted to react. There is no other type of environment for a termite adjusted to live in a large colony of tens of thousands. In behavior termites are children of the mob.

Some data have been procured from new colonies started by a royal winged pair or by a pair of second-form reproductives. It may take a year or two to produce one soldier and half a dozen workers. The stimulating mob psychology is absent. Apparently workers from a large nest which have been born into a mob cannot be removed and stand the quiet of a small group. In the words of Professor Light, "They die of no apparent cause whatever."

We have wondered if this delicate constitution may not be correlated with immaturity. In studies of insects reared from the egg there are so many exceptions that we merely suggest this idea for consideration. But the possibility remains that we are dealing in the termites with an immature behavior, one which apparently has not acquired the partially adult versatility against even small changes in environmental conditions.

We see, then, in a termite colony a great society in which virtually all work is accomplished by immature forms. We see an immaturity that evolution has permitted to spread through the society to encompass a soldier caste, a great worker caste, and finally two reproductive castes of complemental males and queens. For emphasis in discussion we wish to point out that the termite colony is a society based on "child labor."

In passing to a comparison of termite social life with social life among the ants, probably one of the most illuminating diagrams published is one by Fuller, South African termitologist. Figures 24, 25, 26, and 27 are parts of that diagram redrawn from Hegh's copy in *Les Termites*. They compare the incomplete metamorphosis of the life of a termite, in which the nymph is self-supporting from about the second instar, with that of the ant of complete metamorphosis, where the ant can do nothing for itself until it has passed through a larval *and a pupal* state and has come out of the latter as an adult. Thus, by the nature of the type of metamorphosis a termite works through childhood (Fig. 26), whereas the ant (Fig. 27), being a mere grub in its youth, followed



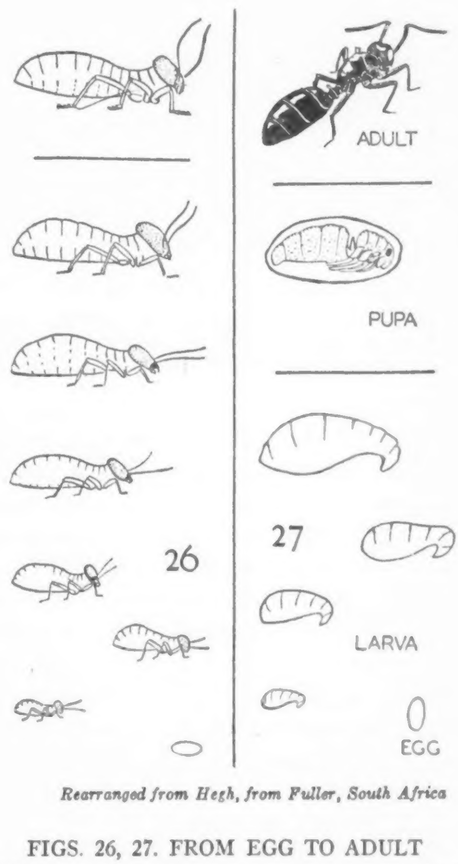
FIGS. 24, 25. ANT VERSUS TERMITE

(24) MATURE WORKER OF A FORMICINE ANT, WITH FULL ADULT STRUCTURE (EXCEPT WINGLESS AND STERILE) AND ADULT BEHAVIOR (EXCEPT IN MATING AND OVIPOSITION). NOTICE THE WAIST WITH "SCALE." (25) THE SO-CALLED "MATURE" WORKER TERMITE: NO WAIST, BODY SOFT AND PALE.

by a pupal state, can do no work until it is an adult. In fact, because the worker termite never arrives at an adult form, since all stages of its active life remain nymphal, it actually has no metamorphosis even of the incomplete type. It remains childlike in form unto death and is actually ametabolic, or without metamorphosis. The winged reproductives have incomplete metamorphosis, as did their cockroach ancestors.

The other life history in Figure 27 is that of any black formicine worker ant. A mature, though wingless, worker is at the upper right. The ant has complete metamorphosis because as a youth it is a grub, which in the fourth instar spins a silken cocoon within which it rests and changes to a pupa and then into an adult. Complete metamorphosis in insects is one of the most versatile energy-saving mechanisms produced by animal evolution. The major life processes are divided into (1) growth in the larva, (2) differentiation in the prepupa (last larval stage) and pupa, and (3) reproduction in the adult. The three different physiological conditions do not conflict with each other. An adolescent ant can waste no energy in its youth by sowing wild oats. She passes into sleep as a fourth-stage baby, passes through metamorphosis while asleep, and wakes up into adulthood. One advantage shows in speed of life history. A termite spends a year or so growing up. An ant grows up in two or three weeks. The greatest body of evidence showing the advantage of complete metamorphosis appears in the development of numbers of species in the higher insects. Those orders with incomplete metamorphosis, excepting the Homoptera, more or less obligate to various plant hosts, have from a thousand to a few thousand species. On the other hand, the higher orders with complete metamorphosis have species numbers in the hundreds of thousands. As an energy-saving mechanism complete metamorphosis works. We shall see how it accumulates energy in larval fat and pours the energies which would be used up in nymphal activities over into the adult, with its fully developed sense organs, its mouth parts, and, especially, its brain; all this for the more active and more highly skilled behavior of adult life.

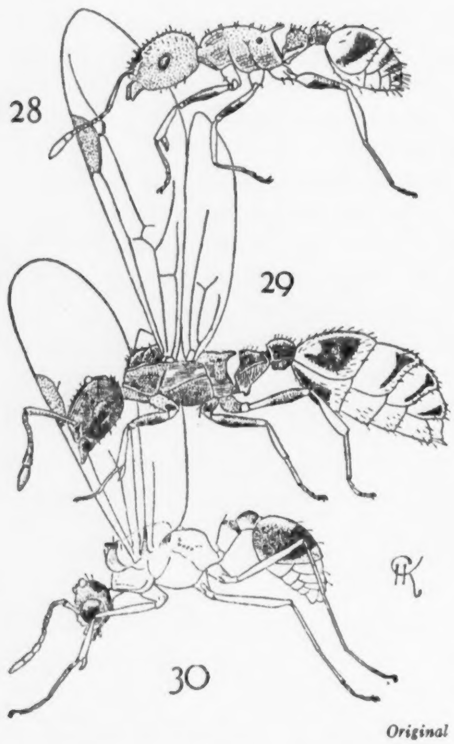
The working ant society is composed of females only. Once a year males appear for a brief period, and die after a nuptial flight of a few days, after which the colonies settle down to another year of purely female activity. Figures 28–30 show the two castes, the first reproductive, composed of the large queen and little male, and the second caste,



Rearranged from Hegh, from Fuller, South Africa

FIGS. 26, 27. FROM EGG TO ADULT

(26) EGG, SIX NYMPHAL INSTARS AND THE SEVENTH, OR SO-CALLED "ADULT," INSTAR OF THE WORKER TERMITE. THE "ADULT WORKER" IS SIMILAR IN STRUCTURE AND HABIT TO THE PRECEDING NYMPHAL STAGES. (27) COLUMN SHOWING EGG, FOUR HELPLESS LARVAE, QUIESCENT PUPAL STAGE, AND AT TOP THE ANT WORKER, A FEMALE MATURE IN STRUCTURE (EXCEPT WINGS AND REPRODUCTIVE SYSTEM) AND MATURE IN BEHAVIOR (EXCEPT STERILE).



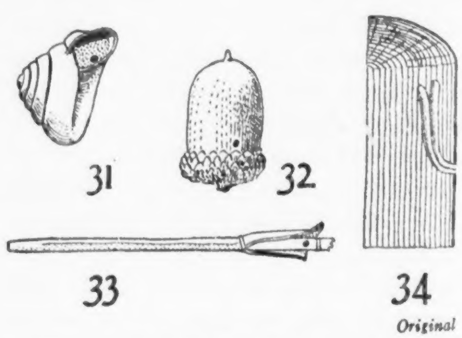
FIGS. 28–30. A MYRMECINE ANT

LEPTOTHORAX CURVISPINOSUS, A MINUTE ANT NESTING IN ACORN SHELLS, ETC. (28) WORKER. (29) QUEEN, BEFORE LOSS OF WINGS. (30) MALE.

ants as we know them, illustrated by a wingless female worker (Fig. 28). All are of the genus Leptothorax, a minute ant which builds colonies in dry plant stems, acorns, nuts, and such minute containers (Figs. 31–34). These are small colonies usually of only fifty to a hundred workers. In other ants there may be two or more castes of workers, such as large-headed soldiers with strong jaws, minute minors, and larger field-workers. Some species may build colonies up to tens of thousands of workers with a dozen or more productive queens.

When we examine the domestic economy of the ant society, we find that the larvae or immature ants, children in our present thesis, do not work beyond, in some species, spinning the silk cocoon used by the pupa. Figure 35 is a diagram of castes and their working schedules in a myrmecine society, where pupae are without a cover or silk cocoon. There is no child labor. Being legless grubs without developed eyes, antennae, and jaws, they merely lie on the floor of the home where placed by the adult female workers. They may be stacked or, as in Stenamma, related to Leptothorax, they may be laid side by side in curving rows. The ant grub cannot use immature organs and immature behavior as used by the child termite. It does not have them to use. *However*, that grub faces the external world *vicariously*. It has the use of the fully mature organs, mouth parts, senses, and, especially, mature behavior of its adult nurse ants, the ant workers. At no time does any ant *child labor* impinge on the internal nest environment or on the vicissitudes of the environment external to the society. All work within the society's walls is done by ants in the adult stage, while all work in the field where the maximum of danger exists is done by the fully developed and fully educated adult. The mature worker honeybee is known to undergo an education of two to three weeks. Little is known about ant education, but it is probably somewhat similar and would occupy the first two or three weeks of adult life.

Compare with the preceding a possible education of the termites, which pass through six or more active instars. Education must be repeated after each ecdysis, or shedding of the skeleton. Some education may be carried over through ecdysis, but



FIGS. 31–34. NO HOUSING SHORTAGE

NESTING PLACES OF SPECIES OF LEPTOTHORAX.

try shedding a skeleton between semesters. In the ant ecdyses are reduced to five and are rushed through in a few days. The forces of the total life energy are stored in the grub as fat, which is transformed later into structures and energy used in a very active adult life. In the latter there is time for two or three weeks of education. The ant newly arrived at adulthood learns at first as a timid, worker-fed callow by exploring the nest, then as a nurse caring for others within the nest, then as a timid explorer in the open near the nest, and finally as a hard-boiled fieldworker that brings home the honeydew and "bacon." And she brings them home.

Every square foot of the world's land surface in warm weather, except perhaps in extreme deserts and high latitudes, is patrolled for food by ants every day. This is a man-sized job, though it is done by lady ants. From scouting picnics to robbing the kitchen, ants are thought of as very busy, persistent, and even nervy creatures. They are in business and mean business. This is mature, adult behavior.

In comparison with the termite workers, which stay at home, eat the house, and depend for protection on ages-old immunities against microorganisms or on the walls of the house and on the defensive efforts of a few stupid soldiers against large enemies, we find that the ants defend themselves by attack. They have never lost their nerve. They travel over the most dangerous environment known, the surface of the ground. Man himself did not reach high intelligence until he came down out of the trees and faced the lions, tigers, wolves, and other dangers of the ground. These dangers speedily eliminated the feeble-minded and made man what we have seen him to have been as a Cromagnon artist and a Greek philosopher. Human populations were weeded vigorously by ground dangers. The ant has always faced the same top dangers.

ADULT LABOR IN A MYRMECINE ANT SOCIETY

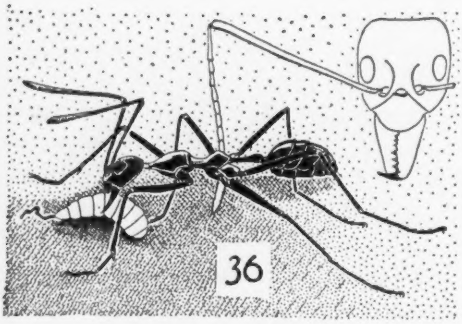
(Assuming a life of 6 instars in all castes)

	Instars 1 2 3 4	Pupa 5	Adult 6	
Queen	....	......	Rears 1st minors	15 years?
Male	....	......	..1 month	
Soldier (1)	....	......	Work-work-work	Adults mature
				in anatomy
Workers (10)	....	......	Work-work-work	and behavior
	....	......	Work-work-work	
	....	......	Work-work-work	
	....	......	Work-work-work	
1 Soldier	....	......	Work-work-work	Adult life
to	....	......	Work-work-work	shortened
10 Workers	....	......	Work-work-work	by intense
	....	......	Work-work-work	activity
	....	......	Work-work-work	
	....	......	Work-work-work	

Original

FIG. 35. CASTES OF ANTS

CHART SHOWING THREE CASTES, REPRODUCTIVE, SOLDIER, AND WORKER, OF A MYRMECINE ANT SOCIETY. ALL WORKERS ARE ADULT, AS IS SHOWN AT THE RIGHT OF THE TWO VERTICAL LINES.



Face from Bingham; ant from Doflein

FIG. 36. A SILK-SEWING ANT

THE ORIENTAL ANT, OECOPHYLLA SMARAGDINA CARRYING A LAST-STAGE LARVA WITH A THREAD OF SILK EXTRUDED FROM THE SILK (SALIVARY) GLAND.

Only perfected behavior could have saved her with her feet on the ground.

Let us review a few of the things into which this vigorous adult behavior has evolved.

Ants are cleanly. The dead are honored with a cemetery, which also happens to be the garbage pile. They are eaten at home only under great pressure of starvation. Defecation of immature forms in the nursery is absent.

Some ants cultivate fungi for food and thus are farmers. Other ants, such as the common yard Lasius, tend herds of honey-dew-producing scales and aphids. They collect the fall eggs of these and in the spring place the young on the correct plant. Some species may even cover their herds of "ant cows" with mud sheds, which protect them from parasitic wasps and syrphid flies. Others become ant robbers and slave makers. Some species are so addicted to slavery that they cannot feed themselves. The slave ants chew the food and put it into their masters' mouths. Some ants are harvesters of grain-producing grasses and have soldier "nutcrackers" that stay at home and hull the grass seeds. Species of our common Formicas clear away young trees from the nests and thus obtain more of the sun's warmth for rearing brood. It is done by girdling the sapling and squirting formic acid in the wound. Some large Formicas build paths, and even tunnels, from nest to nest, apparently merely for greater social life. In the tropics we have the great hordes of army ants that do almost as they please—not a life pleasant to consider, but one of very vigorous adult behavior.

Perhaps the most astonishing thing done by ants is the building of silk-sewn nests by Oriental ants of the genus Oecophylla (Fig. 36). These build nests of living leaves in bushes and trees (Figs. 37–39). A group of workers, on deciding to add another leaf to the house, may have to pull it into position by a living chain as shown in Figure 37 (by Doflein?). Having pulled it into position, they hold it so by the use of jaws and tarsal claws (Fig. 38) while other workers (Fig. 39) go into the nest, select larvae ready to spin the silken larval cocoon, bring these up, and touch the larval mouth where the silk glands empty, first to the edge of one leaf then to the other. The silk hardens instantly, sewing the leaves together. This project, which is one in engineering, is usually called instinctive behavior; we can call a very high-grade adult behavior.

As A summary of our thesis that the work in a termite society is accomplished by child labor, whereas that in the ant society is almost wholly adult labor, we shall review the two bodies of evidence.

1. The termite society is built on incomplete metamorphosis, in which type of ontogeny the young from the first or second instar rustle their living. In Reticulitermes (Fig. 23) the young of all castes work, with the possible exception of those in the first instar, which may depend wholly on food given them by older workers. Workers in the final instar, which caste constitutes 90 percent of the society, retain their youthful sterility, their immature structure, and immature behavior during a life of two or more years of work. The soldiers, males, and queens become dependent in the fifth or sixth instar.

The ant society (Fig. 35) is built on com-

plete metamorphosis. Every caste passes through an inactive larval stage and a quiescent pupal stage and is active only in the adult stage. The males mate and die. With the exception of cocoon production by larvae in some groups, only adult females work. The queen usually builds her first nest and rears her first brood; after this she becomes dependent on her adult worker daughters, which constitute the whole society except for the queen (or group of queens) and reproductive brood for a brief flight season. The queen may live five to fifteen years, but the very active workers probably burn themselves out in one season or less.

2. Structurally, in the termite workers, all organs are of the nymphal or immature type. They are less well developed than if they were developed on into mature forms of the same organs.

In the ant workers, structure, with the exception of wings and reproductive organs, is developed on into the completed adult form. All workers are adults.

3. Physiologically, behavior in the termites is necessarily immature in correlation with immature structure. It is slow, weak, and limited to a few specific activities. The behaviors of hunt, attack, and largely that of defense are absent.

In ants all behavior external to the nest is mature, vigorous, and, as shown in the previous brief of activities, the richest in varied behavior known for any group of insects. (Exceptions are repletes and queens in some parasitic ants.)

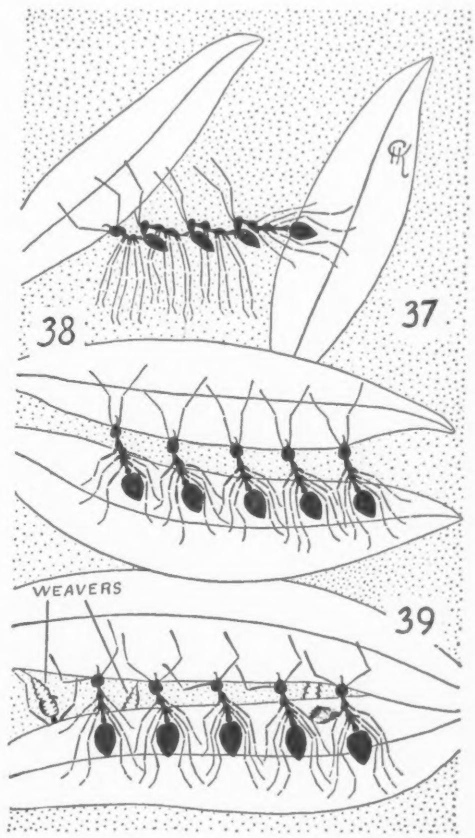
4. The slow nymphal or immature behavior of the termite is correlated with a long (two years) nymphal life and a long (two to five years) last-instar life. The total life energy of the irreversible energy-transforming mechanism is extended over two to five years because it is at a slow, weak level.

The intense adult or mature behavior of the ant is correlated with a short (two to three weeks) larval and pupal life, while the very active aggressive adult life is equally correlated with a short (one season) adult life. The high level of speed, and otherwise more intense behavior, burns up the irreversible energy-transforming mechanism. The ant pays with a short life for its greater adult activity.

5. The termite workers shut within the nest have only the one simple household psychology.

The worker ants have a similar household psychology and a second more vigorous psychology that masters the dangerous environment external to the nest.

6. Education of the termite worker caste during the two years of its nymphal activity is broken by repeated ecdyses.



Redrawn from Doflein

FIGS. 37–39. COOPERATION

(37) OECOPHYLLA WORKERS FORMING AN ANT CHAIN WHICH DRAWS TWO LEAVES TOGETHER. (38) WORKERS ADJUSTING EDGES OF LEAVES. (39) WORKERS HOLDING LEAVES IN PLACE. OTHER WEAVING-WORKERS (SEEN BETWEEN THE LEAVES) WITH SILK-FILLED LARVAE SPINNING SILK ACROSS GAP.

Education of the ant worker caste is a definite period of two or three weeks at the beginning of adult activities. It is not reduced or lost by ecdyses.

7. The problem of the male occurs in all societies. In the termite society he works as a nymph for three or four instars, then evacuates the protozoa from his intestine and, if he happens to mate with a queen or a harem of queens that succeed in reaching reproductivity in a successful nest, is dependent during a long life. The majority of males die in the mating swarm. If successful he lives long and fertilizes the queen or queens at frequent intervals.

The problem of the male in the ant society is solved by the development of a seminal receptacle in the queen where living sperm is retained for fertilization of eggs during years to come. The male dies after the one mating and ceases to be a social liability. His restless antisocial behavior and upkeep are avoided.

8. The lack of wings in the termite worker is correlated with a saving of growth energy. They are not needed within a nest.

The lack of wings in the ant worker is correlated, as in the termite worker, with a saving of growth energy and also with life on the ground external to the nest; it is correlated with the greater intellectual development that comes from life in this, the most intense and dangerous environment known, where feeble minds and concurrent inept behavior are weeded out by natural selection.

Further, the loss of wings, with life on the ground, increases the ant's ability to operate, in feeding the many hungry mouths at home, at a lower temperature than that necessary for the high-speed wing muscles. It also holds speed in the outer environment closer to the low speeds needed within the nursery. The two psychologies, that of the nursery and that used in the external environment, are less likely to conflict when the speed of the latter has been reduced to that needed in walking (or running).

9. Nymphal, or childlike structure, and labor by nymphs in the termite society have evolved into the nymphal form and the nymphal labor of the two or more years of the life of the last worker instar, which is nymphal in lacking even wing pads. With 10 percent of the colony soldiers, 90 percent are nymphs or nymphlike workers with housed-in, childlike behavior.

In the ant society the workers are adult except for sterility and wings. The helpless larvae are fed, cared for, and protected by the adult organs of the nurses and fieldworkers, all adults. Thus even the helpless ant larvae have contacts, though these are *vicarious*, through the adult organs and the adult behavior contacts of their nurses with the nest interior and the dangerous external environment. Immature or child labor does not occur except in the spinning of a cocoon. The adult behavior of the workers is substituted for any child labor.

10. Wasmann has pointed out that, associated with the immaturity of the worker termite, polymorphism is extensively developed in the worker castes of the highest termites, the tropical Termitidae, where as many as eight castes occur in some species. His theory was that polymorphism can evolve more easily in species that are immature in form, that immaturity of form is more mutable: that the germ plasm is subject to more accidents productive of mutations and that probably more forms of rearing by feeding, etc., can occur during long immaturity. But his philosophy too often is not clear.

We believe we have made a case for immature labor of the termite society versus adult labor of the ant society. We believe it is a point of view that can be expressed in the term "child labor," with its associated terms in human sociology, which may permit a more useful comparison with the problems raised by child labor in human society. All are animal societies evolved from that protean energy-transforming mechanism called protoplasm.

THE EFFICIENT UTILIZATION OF METALS*

By ZAY JEFFRIES

Dr. Jeffries (Sc.D., Harvard, 1918) is a Vice-president of the General Electric Company, with offices at Pittsfield, Mass. Before entering industrial research, he taught at the Case School of Applied Science. In 1939 he was elected to the National Academy of Sciences. During the war he was Vice-chairman of the War Metallurgy Committee of the National Research Council and the Academy.

THE world has consumed more metal since the beginning of this century than in all previous history, and the rate of consumption reached an all-time peak during the recent World War. The evidence at hand points to a still greater rate of consumption in the future.

Since the supply of some of the metals is limited and the more accessible and richer ores will be mined out in the foreseeable future, it is necessary that these valuable assets be utilized efficiently. Perhaps a brief statement on the nature and magnitude of the metal industry will provide a helpful approach to the subject of efficiency of utilization.

The metal industry is divided into two fields, ferrous and nonferrous. There is no good reason for the division except that pig iron constitutes around 90 percent of the new-metal production. The nonferrous field includes the metallic products derived from the elements other than iron. If the rare earths are counted, around seventy of the elements are metallic. These metallic elements are major constituents in many nonmetallic products which are not part of the nonferrous metal field. For example the lime and gypsum industries, depending on calcium, are not part of the nonferrous metal industry, but metallic calcium is. In ceramic products like brick, pottery, porcelain, and cement, much more aluminum is used than in the metallic state. The former is not part of the nonferrous metal field, but the latter is. Some nonmetallic products, however, are in a sort of "no man's land." Nonmetallic salts of lead, zinc, and tin may be made from the metals, or the ores may have a common source and may be treated by the same metallurgical processes and, hence, are usually regarded as part of the metal industry.

Rhenium, hafnium, scandium, gallium, radium, and a number of the other metallic elements, including several of the rare earths, are not used in the metallic state, or their use is so small as to be inconsequential. The metals comprising the present nonferrous industry may be divided into two main groups:

1. Metals used in substantial quantities in the pure state or serving as the bases for alloys.
2. Metals used principally as alloying constituents.

In the first group are aluminum, copper, gold, indium, lead, magnesium, mercury, molybdenum, nickel, palladium, platinum, silver, sodium, tantalum, tin, tungsten, uranium, and zinc. In the second group the following are commercially available even though some are used in small quantities: Antimony, arsenic, barium, beryllium, bismuth, boron, cadmium, calcium, cerium, chromium, cobalt, iridium, lithium, manganese, osmium, rhodium, thorium, titanium, vanadium, and zirconium. Plutonium and other transuranic metals should now be classed as nonferrous. Both cadmium and chromium find use in the nearly pure state in the form of electroplated coatings on other metals. Certain elements like carbon,

* From a paper presented at a symposium on "The Efficient Utilization of Materials" at the Princeton University Bicentennial Conference on Engineering and Human Affairs, October 2–4, 1946.

silicon, phosphorus, and sulphur behave in some respects like metals and are very important ingredients of alloys.

Although the tonnage production of all nonferrous metals is only about 10 percent that of pig iron, the dollar value far exceeds that of iron. In some years the value of the gold output alone has been about the same as that of pig iron.

World War II so dislocated the metal industry that it is necessary to take a series of backsights to approximate normal relationships. In so doing, one finds that copper, lead, and zinc dominate the nonferrous field to about the same extent that iron dominates the whole metal industry. The production of manganese, chromium, and silicon is relatively large, but, since these are produced mostly as ferroalloys and are used largely in iron and steel manufacture, they are not ordinarily included in nonferrous figures. Normally, aluminum, tin, and nickel are produced in annual amounts greater than 100,000,000 pounds, and during the war magnesium production exceeded this figure. The annual weight production of all other nonferrous metals combined constitutes only a small fraction of 1 percent of the total.

Our industrial civilization is rich partly because we have so many metals with such varied properties and partly because the metals are available in vast quantities, the world new-metal production sometimes exceeding 100,000,000 tons in a single year. The metal industry is even larger than this because of the recovery and reworking of great quantities of scrap. The steel industry, for example, is so dependent on scrap that the output cannot be used to reflect new-metal production. But the magic of alloying, heat-treatment, and metal-fabrication processes has added immeasurably to the richness.

In addition to the use of several of the metals in a nearly pure state, there are more than 5,000 alloys in use with significantly different compositions. Considering minor differences in composition, the various methods of fabrication, and the different heat treatments, scores of thousands of sets of properties become available for the designing engineers. One might think that the engineers would be overwhelmed with so many varieties from which to choose. On the contrary, they are continually crying for new alloys with combinations of properties not now economically available or not obtainable at any price.

LOOKING back about a hundred years, two phases of the metal industry are clearly apparent: the quantity phase and the quality phase. The quantity phase came as a consequence of the development of the Bessemer and open-hearth steel processes. The availability of large tonnages of steel at relatively low prices created an industrial revolution. Railroads spanned continents, and millions of tons of steel were used for buildings, ships, bridges, machines, and the like. It seemed at times that the demand for ordinary steel would never be met.

The quality phase got well underway in the third decade of this century. Paradoxically, the quantities have been the greater in the quality phase, exemplified by a world production of new metal from 1891 to 1900 of 320,000,000 tons, and from 1921 to 1930 of 760,000,000 tons. The following points reflect the transition from quantity to quality:

1. From 1885 to 1920 the ratio of pig-iron to nonferrous metal production remained about constant at 20 to 1. In 1920 there was a change in slope of the pig-iron production trend line with no corresponding change for nonferrous metals. By 1935 the ratio had changed to 14 to 1.
2. Alloy steel—that is, quality steel—is increasing at a very rapid rate as compared with ordinary steel. Some aspects of this movement are:
   a) Special steels for electrical purposes.
   b) Tool steels rich in tungsten, vanadium, molybdenum, and chromium.

c) Stainless and other corrosion-resisting steels containing large amounts of chromium and nickel.

3. Vastly increased quantities of steel used in the heat-treated condition.
4. The increased use of high-priced metals in combination with steel, including clad, electroplated, spray-coated, and dip-coated steels.
5. The manufacture of products such as wire and rod with dimensional tolerances hardly possible until the middle 1920's.
6. The greatly increased use of thin-walled metal parts, such as tubes, plate, and sheet to make structures of high strength or stiffness with low weight.
7. The increased use of combinations of metals with nonmetals, such as reinforced concrete, and metal inserts in rubber and other plastics.
8. The introduction of a host of nonferrous alloys with properties only dreamed of in the quantity era. Among these are the cemented carbides, alnico magnets, high-temperature alloys that made the gas turbine and jet propulsion practical, and many alloys improved by precipitation heat treatment.
9. Greatly increased use of metal products designed for ease and economy of fabrication, such as deep drawing sheet, free-machining alloys, and alloys adapted to welding processes.
10. The courage on the part of engineers to use higher-priced, long-life metal parts in machine design for quality improvement.

Many other factors could be named, but these should serve to show the quality trend.

The evolution of the quality phase has been spearheaded by metallurgical science. The knowledge of alloying and heat treatment has increased by leaps and bounds during the past several decades. Powder metallurgy has made possible many products not obtainable by other means. The advent of the precipitation hardening principle alone has given rise to some hundreds of precipitation hardening alloys. Formerly it was thought that steel had some special claim on the heat-treatment art, but today alloys rich in all the principal nonferrous metals, including copper, lead, zinc, aluminum, magnesium, silver, and nickel, are available with many properties greatly enhanced by heat treatment.

Broadly speaking, the development of the quality phase in metals has constituted a program working toward more efficient utilization. One might even conclude that the problem of efficient utilization of metals has been solved. As a matter of fact, the movement is only well started, and certain danger signals should be sounded now, even though the troubles will not reach an acute stage during the next few decades.

The consumption of some of our most useful nonferrous metals cannot continue on the present trend line without soon exhausting the richer and more accessible known ore deposits. Fortunately, there is an inexhaustible supply of iron because the earth's crust contains between 4 and 5 percent. Fortunately, also, iron will remain the most important metal for an indefinite period. The cost of production may be expected to increase because the better ores will one day be mined out, but ever-new, less desirable deposits will then be utilized.

Neither will the future of aluminum and magnesium be limited by the supply of raw material. The earth's crust contains between 7 and 8 percent aluminum, and between 2 and 3 percent magnesium, and usable concentrations, including sea water for magnesium, are available in many parts of the world. The long-term outlook is that aluminum and magnesium will assume a position second only to iron in both tonnage and value.

The nonferrous metals expected to be in short supply in the future include copper, zinc, lead, tin, nickel, tungsten, molybdenum, cadmium, bismuth, gold, silver, mercury, and tantalum. It has been estimated that the earth's crust contains only about 0.01 percent copper, 0.004 percent zinc, and 0.002 percent lead. As the richer deposits of all these metals are mined, the use of lower-grade ores will be reflected in higher prices. Higher prices, relatively, will tend to conserve these valuable metals for the uses for which each is best adapted,

which is the essence of efficiency of utilization.

These scarcer metals must be conserved by one means or another. It is even possible that man will exhibit sufficient wisdom in long-term planning to begin this conservation in the not-distant future. The quality era discussed earlier, insofar as it utilizes more of these scarce metals, works against this conservation. The use of more iron, aluminum, and magnesium favors it. In general, substitution of nonmetallics for metals favors the conservation.

Another broad line of attack is also called for. The recent war proved that, while certain of these metals are well-nigh indispensable for specific uses, there are wide overlapping areas in which substitutions can be made with only moderate impairment. Therefore, the increased production of almost any metal will relieve the strain on the scarcer metals. The increased use of iron, aluminum, and magnesium should be stimulated and will be helpful, but it is not enough. A greater future supply of some of the more abundant but less used metals and near-metals would provide additional relief. For example, manganese is sufficiently plentiful to support a large manganese-base alloy industry. This development is now barely started. Certain other elements, like silicon and titanium, can be produced in unlimited quantities if metallurgical science can tame them and adapt them to man's needs. Chromium and zirconium are relatively plentiful, and both need more future attention. Metals like calcium and sodium, available in unlimited quantities, also offer challenges to the metallurgists.

If we visualize such a campaign against the background of metallurgical history, the outlook is not too discouraging. In the first place, there will be a continuing supply of all the metals, the scarcer ones included. We may expect new ore finds of importance, and then there are, in most cases, large deposits of low grade which can be worked at a price. Improvement in mining, milling, and smelting can be confidently counted on to make the working of lower-grade deposits economical. So, the time allowed for making the developments necessary for greater use of some of the wilder but more abundant metals is long, and the advance in metallurgical science is rapid. We can face the future, therefore, with the faith that metals, if properly used, will provide a firm foundation for a much higher world-wide standard of living than anything experienced in the past. Let us hope that world politics, world statesmanship, and world sociology can keep pace with science and technology.

Having arrived at this somewhat comforting conclusion, along come transmutation and nuclear fission. Transmutation, with the advent of many isotopes, would have influenced the metal industry in time. It would have been, and is, another quality factor. It not only *adds* to the number of metals—it multiplies. But nuclear fission and the achievement of the nuclear chain reaction may prove to be a metallurgical, as well as a military, atomic bomb. At least, most of the world is now engaged in a study of how best to utilize uranium.

Perhaps we can agree that the most efficient utilization of uranium will be to end war. Here is a problem that must be tackled by all peoples, but the contribution toward its solution by metallurgists may be of great importance. It is probable that one way to avoid war is to develop healthy peacetime applications of nucleonics. Many of the problems needing solution to achieve this objective are metallurgical. Although the ultimate consequences can be but dimly perceived, nucleonics is certain to greatly enrich metallurgical science and technology, and it will constitute a seven-league-boot stride in the era of quality metallurgy.

NEGRO-WHITE DIFFERENCES IN MENTAL ABILITY IN THE UNITED STATES

By HENRY E. GARRETT

Dr. Garrett, a native of Virginia, received the Ph.D. from Columbia University, where he is now Professor of Psychology and executive officer of the department. During World War II he served as a member of the Committee on the Selection of Military Personnel, Advisory to the Adjutant General's Office. His special fields are learning and mental organization.

THE question of the existence of Negro-white differences in mental ability within the United States has of late been sadly confused with social and political issues of racial superiority, discrimination, and the like. As a result of this confusion, many writers seem to take the position that racial differences ought not to be found, or if found should immediately be explained away as somehow reprehensible and socially undesirable. With this attitude the present writer is in sharp disagreement. While he is heartily in favor of every genuine effort to aid the Negro in improving his status as an American citizen, he does not believe it is at all necessary to "prove" the nonexistence of race differences in order to justify a fair policy toward the Negro. It cannot be said too often that the honest psychologist, like any other true scientist, has no racial bias; he does not *care* which race (if any) is the more intelligent or whether all races are potentially equal in mental ability. But he *is* interested in discovering whether differences in mental ability exist, and in making inferences concerning the origin of such differences. And this would seem to be an entirely legitimate enterprise.

A study of Negro-white differences in the United States offers certain advantages—as well as disadvantages—to the student of racial psychology. A decided advantage is the fact that Negroes and whites have lived side by side in our country for more than three hundred years. The American Negro's native language is English, and he has been exposed to the same manners, customs, and environmental influences (schools, churches, movies, etc.) as the American white. On the other hand, the American Negro is generally below the white in social and economic status, and his opportunities for other than menial work are limited. The educated Negro, for instance, is restricted in his business and social contacts largely to members of his own race. While this inequality in social status makes it difficult to obtain a fair comparison of American Negroes and American whites, this can be done if proper precautions are taken. Inferences drawn from many comparisons, however, must of necessity be tentative.

Other important considerations arise in a study of Negro-white differences in mental ability within our country. The admixture of Negro and white stocks has gone on steadily over the years so that the present American Negro is rarely of pure African ancestry. Comparisons of Negroes and whites within the United States can hardly reveal *true* race differences, therefore, and are really comparisons of white and Negroid (more or less Negro) groups. Suppose, for example, that the evidence shows Negro-white mixtures to be more intelligent than pure Negroes. If differences in mental ability are found in favor of whites, then, one may infer that true racial differences would be greater if African Negroes and white Europeans were studied under comparable conditions.

How does the American Negro compare with the American white in measured ability? What are the *facts* apart from questions of segregation, considerations of social be-

havior and customs, "racist theories," and the like? Perhaps these questions can best be approached stepwise: that is, by comparing the performance in mental tasks of American Negro and American white from childhood up through adulthood.

We may begin with McGraw's study in 1931 of the comparative abilities shown by 68 white and 60 Negro babies, two to eleven months old, all living in a Southern community. This study is valuable in spite of the small samples because social influences are minimal if not completely absent at these early age levels. Each baby was given a series of mental tests constructed for use during the first two years of life. The tasks involved activities designed to measure coordination and control, manipulative skill and development, memory and imitation, and elementary "reasoning" as exhibited in the solution of simple problems. For each child a "developmental quotient" was calculated to show the baby's mental development as compared with infants of his own age level. If the baby is as alert as the average of his month level, his D.Q. (developmental quotient) is 100; and this is the base from which to figure. The average D.Q. of the 68 white babies was 105, slightly better than expectation; of the 60 Negro babies, 92—eight points below expectation. The groups were about equally variable around their respective means. The white babies' D.Q.'s were better than those of the Negro at each month level from two to eleven, their superiority ranging from 2 to 25 points, and averaging 13 points. In percentage of total number of test situations done correctly, the white babies' superiority over the Negro babies averaged 12 percent. Just 28 percent of the Negro children exceeded the average D.Q. of the white babies.

These differences cannot be explained as due entirely to the better nutrition of the white babies or the better education of their parents. To be sure, the white babies were slightly taller and somewhat heavier than the Negro children. But a comparison of each group with the standard height-weight measurements given for the United States as a whole shows the Negro children to be as typical (close to the norms) of their age levels as were the white children. The educational level of the white parents was somewhat higher than that of the Negro parents, but the difference was not great. The average Negro parent reported six grades of schooling, and many reported college and normal school attendance. The average white parent reported high-school training, but many had attended only the elementary school. Three features of this study are noteworthy. First, environmental influences were minimized if not eliminated, and differences still appeared; second, the white babies became increasingly better as the upper and more difficult levels of the scale were reached; and third, considerable overlap in achievement was found—that is, about one-fourth of the Negro children performed better than the typical white baby.

The scores of Negro school children on standard intelligence tests are usually reported in terms of I.Q., for which the norm for white children is 100. A very large number of investigations of the comparative abilities of Negro and white children, both in the South and in the North, have been carried out. These studies differ markedly in the size and adequacy of the samples measured and in the validity of the mental tests employed. But they are consistent in giving the Southern Negro child an average I.Q. rating of about 80 and the Northern Negro child a slightly higher average, 85–90. Not all this retardation appears to be a matter of restrictive environment, though some of it undoubtedly is. In one study in which white and Negro children were really equated for social and economic status, the difference was much reduced, but it may be noted that even the white children of inferior and very inferior social status were 7–10

I.Q. points ahead of the Negro children. This same result has been found for a group of nearly 1,000 Negro and white children tested in a rural section of Virginia. Even the Negro children in a relatively favorable environment (Los Angeles, for example) do not average more than 105 I.Q.

Until test results from World War II are available, the best data on the comparative achievement of American Negro and white adults are provided by the intelligence tests given to nearly 1,750,000 soldiers in 1917–18. Two mental examinations were used in World War I, known, respectively, as Army Alpha and Army Beta. Alpha was a verbal, or language, test, requiring the ability to read and write. Beta was a nonlanguage test. The subject did not have to read or write, but simply indicated his answers by marking with a pencil. White soldiers scored higher on both Alpha and Beta than Northern Negro soldiers, who, in turn, scored higher than Southern Negro soldiers, as shown in Table 1.

TABLE 1

	Alpha Median	Beta Median
White soldiers	58.9	43.4
Northern Negro soldiers	38.6	32.5
Southern Negro soldiers	12.4	19.8

It has often been asserted by uncritical writers that the Negro performed relatively much better on Beta than on Alpha, and this is interpreted to mean that the lower score of the Negro on Alpha is a reflection of inadequate schooling rather than a function of poorer native ability. This conclusion does not follow from the data. Alpha and Beta were scored in different units, and a 20-point difference on Alpha cannot be compared directly with a 10-point difference on Beta. If the proportions of Northern Negro soldiers who scored better than the average white soldier in Alpha and Beta are computed, it is found that 29 percent of the Northern Negro soldiers exceeded the average white in Alpha, and 27 percent exceeded the average white in Beta. The Negro soldier lagged to about the same degree, therefore, whether the test was for literates or illiterates. When Negro and white soldiers were compared on a country-wide basis in terms of the "combined scale" (a test made up of prorated scores on Alpha, Beta, and individual examinations), about one Negro soldier in seven or eight did as well as the average white soldier.

As shown in Table 2, Northern Negro soldiers from New York, Ohio, Illinois, and Pennsylvania scored somewhat higher in the Alpha examination than Southern white soldiers from Georgia, Arkansas, Kentucky, and Mississippi. This finding has often been cited as evidence for the view that Negro-white differences in mental test performance are fundamentally environmental and are not genetic or native. Again it must be said that this conclusion (though it may be partly correct) does not follow from the data. In the first place, Table 2 represents extreme and rather small selections. When Negroes in the four Northern states are compared with whites in these same states, the overlap is 28 percent, almost exactly what it is in the country as a whole. One might argue, therefore, that given better schooling the Negro does indeed improve

TABLE 2

MEDIAN SCORES OF SOUTHERN WHITES AND NORTHERN NEGROES IN CERTAIN STATES (Alpha Only)

Whites			Negroes		
State	N	Medians	State	N	Medians
Georgia	702	41.6	New York	850	44.5
Arkansas	618	41.0	Ohio	152	48.8
Kentucky	832	41.0	Illinois	578	46.9
Mississippi	665	40.8	Pennsylvania	498	41.5

his Alpha score—but not his position relative to the white. Again, one might argue in favor of race differences on the ground that white Southerners performed as well as highly selected Northern Negroes in spite of educational handicaps which, unfortunately, affect whites as well as Negroes.

The better showing of the Northern Negro as compared with the Southern Negro has often been explained by the "selective migration" of the more intelligent Negroes to the North. Selective migration is disputed by writers who favor the environmental explanation of Negro-white test differences. These insist that as often as not it is the shiftless and ne'er-do-well Negro (of presumably low intelligence) who leaves the South for the North. Several studies made in 1935 by Professor Otto Klineberg bear directly upon this problem of selective migration. It is worth while examining Professor Klineberg's evidence with some care, as many writers think it disproves the selective migration hypothesis and favors the environmental explanation. As recently as 1946, for example, one psychologist wrote that the argument for selective migration has been "largely invalidated" by Klineberg's work.

In his first study, Klineberg compared the school grades of 562 Southern Negro children, whose parents had recently come North, with the grades of their schoolmates still in the South. All school grades were expressed in a simple scale in which 50 represents average performance. In two of the three Southern cities (Nashville and Charleston) the migrating children were somewhat better than the nonmigrating, their averages being 54 and 56; in the third city (Birmingham) the migrating Negro children averaged 45—below the nonmigrants. For the entire group of 562 migrating children, the average was 49, which on the face of it offers no evidence for selective migration. But unfortunately this result offers no evidence *against* selective migration, either. Dr. Leta S. Hollingworth, an eminent child psychologist, has pointed out that a difference of 20–25 points in I.Q. is usually necessary before teachers recognize clearly the gap in mental ability between two children and reflect this difference in their school marks. The average I.Q. of the Southern Negro child, it will be recalled, is about 80. The migrating Southern Negro children would have had to possess I.Q.'s of 100–105 on the average, therefore—significantly higher than that of the average Southern Negro child—for Klineberg's method to have found them superior in their school marks to their nonmigrating classmates. It may be added, furthermore, that the migrating children were taken North by their parents, and that the relation of intelligence in parents and offspring is not perfect. Even if the migrating children were no more intelligent than the nonmigrants, therefore, we cannot say that their parents, who initiated the migration, were no more intelligent than their neighbors who stayed behind.

In a second study, Klineberg compared the scores on several standard intelligence tests made by twelve-year-old Negro children whose parents had lived from one to twelve years in New York City. Two facts emerged from this study: (1) The average scores made by the Negro children were better the longer they had lived in New York City. (2) The twelve-year-old Negro children, both the migrants and those born in New York City, were from six months to one and one-half years in "mental age" behind white children of the same age level. Environment did indeed raise the scores of these Negro children, but even under relatively favorable conditions it did not bring them up to the white standards. This same result, it will be remembered, was found when the Alpha scores of Negro soldiers in Northern states were compared with the Alpha scores of white soldiers in the same states.

The fact that bright and very bright

American Negro children can be found in American schools is often cited as another argument that environmental and not native factors account for Negro-white differences in performance on mental tests. In one well-known study, a systematic search was conducted for superior Negro children in Grades III–VIII of seven Chicago public schools in which approximately 8,000 Negro children were enrolled. Altogether, 103 children were located with I.Q.'s of 120 or above on the Stanford-Binet Intelligence Test. Of these superior children, about one-fifth reported no white ancestry, the remainder being of mixed Negro and white ancestry in varying degree. The parents of these children were above average in education and in social and economic status.

It is difficult to see why this study should be regarded as so strongly favoring the environmental hypothesis. No responsible person to my knowledge has ever claimed that *all* Negroes are less intelligent than *all* whites. As has been shown above, *at least* 25 percent of American Negroes, whether children or adults, achieve scores higher than those of the average American white, and this overlap in score allows for many bright and very bright Negroes. At the same time, it should be pointed out that in a sample of 8,000 white school children at least 800 can be expected to possess I.Q.'s of 120 or higher. This means that only one-eighth as many bright Negro as bright white children will probably be found in the general school population even under exceptionally favorable conditions.

The facts brought out in this survey may be briefly summarized as follows:

On tests of mental ability, American Negroes on the average rank consistently lower than American whites. The regularity of this result from babyhood to adulthood makes it extremely unlikely, in the present writer's opinion, that environmental opportunities can possibly explain *all* the differences found.

Approximately 25 percent of Negroes do better than the average white, and many make very high scores. Under favorable conditions, about one-eighth as many bright Negroes as bright white children can be expected in our schools.

Neither the selective-migration hypothesis nor the environmental theory is a complete explanation of the differences found between American Negroes and whites, or between Northern and Southern Negroes.

The point may be stressed again that the differences between American Negroes and American whites are not true racial differences. What differences would be found between African Negroes and European whites is not known, but it is a fair assumption that they would be greater than the differences found between whites and Negroids in the United States.

A LETTER

By Paul D. Harwood

Dear Marjorie:
In Houston all this fall
I've watched the slow and colorless dropping of the leaves.
As their time nears, they turn a duller green,
And next one sees them all upon the ground—
A motley heap of yellow mixed with brown.

I had not thought to miss the autumn's riot so;
The panoramic never held me with its awful sweep,
Instead I've looked for beauty in some little thing—
Such as the caddice case, the lace-bug's wing.

Our trees are nearly bare except live oaks
Whose dark, thick leaves outlast the sun's decline.
And yet, today, I came upon a myrtle bush
Whose every leaf had turned a deep, bronze red.
Quite suddenly I was alone amid a crowd,
And I've returned to worship when my time allowed.

Among the yellowed host of maple trees
Above Cayuga Lake, we've known white oaks
Whose leaves have turned this bronzy red
Where they were mixed upon the long, steep hill
With other oaks whose leaves were redder still.

Because we shared all that last fall,
Nostalgia holds my heart tonight.

Yours,
Paul

THE STORY OF ETHYLENE

By ERSTON V. MILLER

Dr. Miller (Ph.D., Michigan State, 1926) was, until recently, a plant physiologist with the Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, U.S.D.A., at Orlando, Fla. He has resigned in order to accept a professorship in the Department of Biological Sciences at the University of Pittsburgh. Formerly in academic work, he spent three years as an instructor in science at the Shanghai (China) American School and one year at Michigan State College before entering the Bureau of Plant Industry.

ETHYLENE is a colorless hydrocarbon gas with a sweetish odor, having the formula C_2H_4. It belongs to the unsaturated group of hydrocarbons called "olefins" and, because of its unsaturation, it combines readily with bromine and chlorine. The organic chemist finds this hydrocarbon gas useful as a starting point in the manufacture of a great variety of substances of commercial value. Tetraethyl lead, which is used by the petroleum industry in the manufacture of "ethyl", or antiknock, gasoline, is derived from ethylene. In medicine ethylene has found use as an anesthetic and in some respects is believed to be superior to ether. But we are concerned in this article with the role of ethylene in the field of plant physiology.

To begin at the beginning we must turn back the pages of history to the time when the Chinese ripened hard pears by placing them in closed rooms with burning incense. They ripened the pears in this manner "because their fathers before them did so." Little did the Chinese people realize that in the smoke from the incense was this gas called ethylene, a compound capable of influencing physiological processes of fruits, vegetables, flowers, flower bulbs, roots, tubers, and germinating seeds, and so potent a substance as to be able to make its presence known, in some instances, when present to the extent of only one part in sixty million parts of air.

But the Chinese are not the only people who have utilized ethylene without knowing it. At the beginning of the present century it was customary to ship oranges from Florida to Northern markets in railroad cars heated with kerosene stoves to prevent freezing. At the time it was noted that the green-colored fruits in the car assumed the characteristic orange color during transit, but this was considered merely a ripening process caused by the heat generated by the stoves.

In 1912 Sievers and True, working with lemons, showed that the active agent bringing about the color change was to be found in the products of incomplete combustion of the kerosene stove and that heat was of secondary importance. Furthermore, the fruit could be "degreened" by the exhaust gases of a gasoline motor. However, the actual identity of the coloring agent was still unknown. In 1923 Denny suspected that this strange gas was an unsaturated hydrocarbon because he found that the fumes of the kerosene stove were rendered ineffective as a coloring agent if they were first filtered through bromine water. Ethylene was a well-known unsaturated gas at that time, although its properties as a coloring agent were unsuspected. But when Denny substituted small quantities of pure ethylene for the kerosene fumes in the coloring of citrus fruits, he found the ethylene gas much more effective. Thus began the practice of degreening citrus fruits with ethylene on a commercial scale.

For years now the ethylene treatment has been given to early oranges, such as Parson Brown, Washington Navel, and Sat-

suma, as well as any other variety of orange or grapefruit that fails to color properly on the tree because of having grown in the shade of dense foliage. The Valencia (late) orange usually develops a good yellow color in the winter while still immature and then turns green at the stem end as it matures in the spring. These fruits are given the ethylene treatment to remove the green pigment (chlorophyll) from the rind. Lemons are picked according to size and not color, and the green ones are colored by storing at 50°–55°F. for 30–60 days before marketing, unless the demand is brisk, when they are subjected to forced curing, or coloring, with ethylene.

After the citrus industry, the banana industry was perhaps the next to make a commercial practice of using ethylene. Because of their softness, ripe bananas cannot be shipped from the tropics to the markets. For years, therefore, it had been customary to ship mature green bananas and ripen them at their destination with kerosene stoves. Following the discovery of the effect of ethylene on physiological processes of fruits, this gas has been used to hasten the ripening of bananas. One of the main advantages in using ethylene rather than kerosene stoves for this purpose is that a much lower temperature may be employed, thus reducing the amount of decay.

After Denny reported that ethylene was more effective than the fumes of kerosene stoves in coloring citrus fruits, physiologists began experimenting with the coloring and ripening of other fruits and vegetables. In 1925 R. B. Harvey reported on a new method for blanching celery. Harvey recalled that in 1908 certain greenhouse operators in Chicago had reported that rosebushes were being defoliated and that leaves of other plants were becoming etiolated, or blanched. Crocker and Knight had been called in to investigate and found that gas was leaking from the city mains and that the ethylene in the gas was responsible for the peculiar physiological effects on the greenhouse plants. It was this report that suggested to Harvey that ethylene might be used for blanching celery. At the time it was customary to blanch celery in the field by placing boards, paper, or soil around the plants and leaving them so enclosed until the green pigment in their stalks disappeared. This process required 8–10 days. When ethylene was used in the blanching process, the time could be reduced one-half. In some sections of the country the ethylene method for blanching celery was adopted by the industry but was abandoned later when it was learned that enlargement of celery "hearts" occurred only during field blanching.

During the ensuing years ethylene ripening was recommended for tomatoes, pineapples, cantaloupes, dates, jujubes, persimmons, pears, mangoes, pomegranates, peppers, avocados, honeydew melons, apples, plums, papayas, chayotes, cherimoyas, plantains, endive, chicory, and rhubarb.

It was found during these investigations that ethylene merely acted as a trigger in setting off the enzymatic processes which bring about coloring or ripening. Perhaps it would not be out of place at this point to discuss some of these processes, at the same time describing some of the differences between the changes taking place in fruits that are ripened by ethylene and in those that are only colored in the process. It has been emphasized by many students of this subject that the ethylene treatment of citrus fruits consists of a "degreening" and not a ripening process. The green pigments are destroyed in the process, revealing the yellow pigments, which were present all the time but which were masked by the green pigments. Analyses have shown that sugar is not increased, that acids are not decreased, and that vitamin C is not affected by the ethylene gas. It is obvious, therefore, that ethylene is only a coloring agent insofar as citrus fruits are concerned.

When oranges ripen during warm weather, like the early varieties in Florida, and reportedly all varieties in tropical countries, they may become edible before they lose all their green color. Residents of the tropics are accustomed to seeing green oranges, and they accept them. On the other hand, since most of the varieties in the United States ripen during cold weather and are fully colored, the consumer is prejudiced against a green-colored orange. This has given rise to the practice of coloring or degreening early oranges and certain other citrus fruits with ethylene.

Most of the fruits and vegetables mentioned in this article can be actually ripened with the use of ethylene gas. Fruits like the apple, pear, and banana are usually picked in the "mature green" stage and are permitted to ripen after removal from the tree. Ripening in this case consists of an increase in sugar content, a loss of acidity, in some instances a loss of astringency, and a general improvement in texture and flavor. Softening is the result of conversion of protopectin into pectin. The increase in sugar is made possible by the presence of a "carbohydrate reserve" in the mature green fruits, which is hydrolyzed into sugar during ripening. These processes proceed whether the fruits are left on the tree or harvested, although there are often more advantages in harvesting in the mature green stage and permitting the fruits to ripen at an optimum temperature in storage than in harvesting them ripe. The ripening processes can be hastened by using ethylene.

Citrus fruits do not have a carbohydrate reserve and do not undergo a softening during ripening, so that they must be ripe when harvested if they are ever to be ripe at all. Before oranges can be colored with ethylene they must first meet certain standards of maturity which have been established by regulating agencies in the state in which the fruit is being produced.

Specifically, therefore, the fruits that may be picked in the mature green stage and ripened after harvest are the ones that can be ripened with ethylene. In certain fruits, like the pineapple, that do not possess a carbohydrate reserve, increased sweetness has been shown to be the result of the inversion of sucrose. Reduction of acidity also accounts for improvement in flavor during ripening of many fruits. In one type of fruit, ripening is accompanied by a reduction in astringency. The banana, date, and persimmon belong to this group. Astringency in the green fruits is caused by the presence of soluble tannins. It has been shown that during ripening, with or without ethylene, the tannins are not destroyed but are rendered insoluble by being combined with colloidal carbohydrates.

Tomatoes are both colored and ripened by ethylene, and coloring in this instance is more than just a degreening because the orange-red pigments actually increase in quantity during the process. The color of a ripe tomato is due largely to lycopene, an isomer of carotene, and it has been observed that lycopene continues to develop in fruits after removal from the vine. If oranges are held an extra day in ethylene, the color of the rind deepens, although the total quantity of carotenoid pigments does not increase. There apparently occurs a shifting of carotene or some other pigment to lycopene. Occasionally a grower will subject fully colored oranges to ethylene in order to enhance the color a little. However, unnecessarily prolonging the ethylene treatment of oranges is to be discouraged because such a practice increases the fruit's susceptibility to decay.

One general effect of ethylene on all fruits and vegetables, whether they are colored or ripened, is to increase the rate of respiration. It has been shown, for example, that the ethylene treatment of lemons may increase the respiration rate 100–250 percent. The astonishing feature about this gas is the low concentrations in which it is effective. Ex-

periments have demonstrated that the respiration rate of lemons may be increased by ethylene in concentration of 1 part to 100 parts of air, 1 to 10,000, 1 to 100,000, or even 1 to 1,000,000, although the best coloring was obtained in these experiments in the intermediate concentrations (1 part of ethylene to 10,000 or 100,000 parts of air). When ethylene is used as an anesthetic for humans, four parts of ethylene are required to one part of air.)

An attempt has been made to show that ethylene stimulates the natural processes in fruits and vegetables and serves to bring about, in a short time, changes that would occur in nature only after a much longer period. The claims that certain ethylene-treated fruits are sweeter than the untreated ones were doubtless based on analyses made simultaneously on treated and untreated fruits. The ethylene-treated fruits, naturally being riper than the controls, would be sweeter. In more recent years analyses made on control lots, after they had attained the same degree of ripeness as that of the ethylene-treated lots, showed the same chemical composition. Thornton, in his paper published in *Food Industries* (12 [7]: 48–50; [8]: 51–52, 1940), entitled "The Facts about Artificially Ripened Fruit," emphasizes this point by citing references from all over the world that cover a large number of fruits and vegetables.

THERE are three distinct parts to this story. First, it will be recalled, oranges were colored with kerosene fumes, and pears were ripened with incense smoke, but the active constituent of these fumes was not known. Second, it was learned that ethylene was an effectual coloring and ripening agent. The third phase began with the discovery that a physiologically active gas was being evolved by ripening fruits in storage.

In 1910 the annual report of the Jamaica Department of Agriculture contained a statement by Cousins that bananas ripened faster when stored in the same rooms with oranges. Recommendations against mixed storage of fruits were made and apparently the matter was dropped there. This brief report on so vital a matter was either forgotten or overlooked for a number of years, and it was not until about thirty years later that this fruit-ripening gas evolved by oranges was identified as ethylene.

Meanwhile the United Fruit Company was having difficulty with shipments of bananas from the tropics. It was reported that the more mature bananas, though green when loaded aboard ship, would ripen during the trip from the tropics and affect normal green fruit adjacent to them, so that they would be too tender to be handled or distributed through trade channels after arrival at port. This problem was eventually solved by use of forced ventilation and refrigeration. Since it was found that the number of "ship ripes" varied with the amount of carbon dioxide produced by the respiration of the bananas, it was incorrectly concluded that carbon dioxide was the gas that was responsible for this artificial ripening. In 1923 Ridley, of the United Fruit Company, demonstrated by carefully controlled experiments that something produced by ripening bananas would accelerate the ripening of green fruits, and that this substance was not any of the then known by-products of metabolism of the banana. This unknown substance was called "X-gas."

In 1930 Chace and Sorber announced that a by-product of ripening pears would accelerate the softening of green pears. In 1932 Elmer reported that when apples and potatoes were stored together, the sprouting of the potatoes was inhibited. Interest in gaseous emanations from ripening fruits was now becoming widespread.

It was difficult to identify ethylene in these gaseous emanations because the gas is usually present in such very minute quantities. Identifying a substance that may be

physiologically active in concentration of two parts per million offers a challenge to the analytical chemist. It is therefore fortunate that biological methods of detection of ethylene were first employed. The method was discovered accidentally. In 1933, Botjes in Holland, and Huelin in Australia, each reported that the vapors of stored apples would produce epinasty in certain potted plants such as tomato or potato. In an epinastic plant the cells on the upper surface of the branches or leafstalks grow faster than those on the underside, with the result that the branches turn down and grow tightly against the stalk. At first glance the plants appear to have wilted, but closer inspection reveals no shriveling of the leaves. Also, when the leaves are pulled up into normal position and then released, they snap back into the depressed position.

The belief that the active constituent of the apple vapors was ethylene was based on the reports of E. M. Harvey in 1913 and of Doubt in 1917 that, when plants like the tomato were exposed to traces of ethylene, an epinastic curvature of the petioles would develop in the test plants.

During the next three or four years a number of attempts were made to identify this unknown gas. Kidd and West (1933) reported experiments that proved that the physiologically active substance in apple vapors was a hydrocarbon; and the work of Smith and Gane, during the same year, indicated that the substance might be an olefin or some complex hydrocarbon. The field of search had been narrowed in 1932 when Crocker, Zimmerman, and Hitchcock tested thirty-eight gases for their ability to produce epinasty in plants and obtained positive results with only five. These were ethylene, propylene, butylene, acetylene, and carbon monoxide. Although these tests had narrowed the search to five gases and had pointed to an unsaturated hydrocarbon, or olefin, they also served to show that the biological test (epinasty) was not specific. Following this, considerable attention was given to identifying the active gas by the process of elimination. In 1936 Elmer, analyzing the volatile products of apples that are absorbed in fuming sulfuric acid, concluded that the hydrocarbon was ethylene rather than one of its homologues. Hansen and Hartman in 1935, and Denny in 1938, eliminated the possibility of butylene and propylene by filtering the gaseous emanations through 87 percent sulfuric acid, removing any acetylene that might be present by absorbing the gas in a solution of mercuric nitrate and then liberating pure ethylene by adding hydrochloric acid. As early as 1934, however, Gane had rather conclusively proved that apples evolve ethylene. The method consisted of absorbing the gaseous emanations in bromine and converting the ethylene dibromide thus formed into crystalline diphenyl ethylene diamine. In these experiments Gane led a stream of air over sixty pounds of apples and then through bromine at $-65°$ F. for one month. At the end of this period he had collected only 0.85 grams of an oily substance. He concluded that "the amount of ethylene produced is very small, perhaps of the order of one cubic centimeter during the whole life of the fruit."

It will be noted that during these years of search for the identity of the unknown gas present in the volatile emanations of fruits, the investigations were being conducted with such fruits as apples, pears, and bananas. Except for an isolated and almost forgotten report from Jamaica, citrus fruits were not mentioned. The subject of oranges and ethylene in this connection arose only after public attention had been focused upon coloring processes employed by the citrus industry. "The color-added" process, a method of dyeing the orange rinds to enhance the color, was claimed by certain groups to be an adulteration of a food product and was often confused with the ethylene method of coloring. Moreover, when

coloring of any kind was mentioned, ethylene usually entered into the discussion, and research workers were often asked if ethylene degreening of citrus fruits were not an artificial process. This question was put to the plant physiologists, and investigations were begun on the volatile substances evolved by citrus fruits in storage. E. M. Harvey, who had been a pioneer in studying the physiological effects of ethylene on growing plants, had observed that potato plants showed abnormal growth when placed in rooms where lemons were stored. He suggested to several of his co-workers that this phenomenon indicated the presence of some such substance as ethylene, and that there was a probability that this gas was being evolved by decay-producing fungi in the storage rooms.

In 1940 it was independently reported by Biale in California and by Miller, Winston, and Fisher in Florida that oranges actually evolve ethylene gas, that decaying fruits produce the gas more abundantly than normal fruits, and that *Penicillium digitatum*, a decay-producing organism, may produce significant amounts of this gas.

The discovery that ethylene is evolved by ripening oranges was of considerable significance to the citrus industry because it meant that the ethylene treatment could no longer be considered artificial coloring; that is to say, the method for degreening of oranges merely involves the use of larger quantities of a gas that is already being evolved by fruits and vegetables.

When the subject is considered as a whole, it becomes evident that both good and bad effects are produced by ethylene emanations. Reference has been made to the losses of banana shippers when bananas were prematurely ripened and made too soft to handle. Effects on apples also may be deleterious. It had been realized as early as 1917 that volatile substances from apples in storage were responsible for the development of scald in these fruits. Qualitative analyses of apples at the time revealed a number of substances, like alcohols, aldehydes, and esters, that are responsible for giving the apple its flavor, but ethylene was not suspected and not detected. Knowing that volatiles were responsible for scald was a step forward, and in a few years still more progress was made when it was discovered that oiled paper wraps on apples would absorb the volatile substances and reduce scald. It was not long after this that oiled wraps and shredded oiled paper were used in every apple country of the world. This practice likewise created a new type of business for paper manufacturers.

The role of ethylene in the production of apple scald was not suspected until 1942, when it was observed at Cornell University that the quantity of volatile material arising from McIntosh apples harvested in 1941 had been much higher than that in fruit harvested in 1942 and that the severity of scald likewise had been more severe in stored apples from the 1941 crop. The connection between ethylene and apple scald was demonstrated later (1945) when satisfactory control measures were obtained by filtering the storage atmosphere through activated charcoal impregnated with bromine. This type of filter removed all ethylene from the apple vapors. The work at Cornell and similar work at other institutions has reopened the subject of storage scald of apples, with the result that a number of investigations in this field are now underway in various parts of the country.

The effects of ethylene in the storage atmosphere are not restricted to fruits and vegetables. Prior to 1941, commercial flower growers had claimed that cut flowers could not be held very long in cold storage. Investigation by the U. S. Department of Agriculture at Beltsville, Md., indicated that the storage life of cut flowers was shortened by holding them in storage rooms with certain fruits. For instance, when stored in the same room with apples, carnations developed

what is known as "sleepiness;" that is, they tended to close after having once opened. Under the same conditions roses opened prematurely and then began dropping their petals. Snapdragons quickly shed their petals, and the inflorescences of stocks (*Matthiola*) soon faded and became yellow. Narcissus flowers showed premature fading, discoloring, and shriveling. To make a long story short, carefully controlled experiments showed that it was the ethylene in the apple vapors that was causing the cut flowers to deteriorate so rapidly in cold storage. This could be prevented by storing flowers in one compartment and apples in another, and recommendations to this effect were immediately made to the industry.

The fact that decaying fruit and even decay-producing fungi evolve ethylene is of extreme economic importance. It has been reported, for example, that 1 percent of green mold decay in stored lemons will produce enough ethylene to approximately double the respiration rate of all lemons in the room. This emphasizes the need for controlling decay and the maintenance of sanitation in storage rooms. It has also been claimed that ethylene treatment of oranges and lemons reduces the "jelly-unit" yield of pectin that may be extracted from the rinds after the fruits have been stored.

The inhibition of the sprouting of potatoes by ethylene may at first appear like an advantage. In itself it is; yet the effect is accompanied by an increase in sugar, and this is not always an advantage. A high sugar content in stored potatoes is objectionable if they are to be used for "French fries" or "chips."

Much can be counted to the credit of ethylene in its physiological effects on plant material. Hastening the coloring of citrus fruits and the ripening of such fruits as the banana, pear, and persimmon, can be decidedly advantageous, as has already been pointed out. According to Marloth, ethylene has been successfully tried on bananas, plantains, tomatoes, mangoes, grapefruit, celery, pineapples, melons, persimmons, limes, lemons, dates, jujubes, pears, papayas, chayotes, cherimoyas, endive, chicory, and rhubarb. Chace and Sorber, 1936, found that ethylene could be used to speed up the natural reactions that result in loosening the hulls of English walnuts of which the kernels are mature but the hulls remain attached. Here ethylene brought about only such changes as would have occurred normally over an extended period of time. It was claimed sometime later that the extent of the use of ethylene for husking walnuts in California was second only to its use in citrus coloring. Ethylene has been found to stimulate the rooting of cuttings, but the use of rooting compounds (hormones) is now much more practicable. It has been reported that ethylene stimulates the fermenting action of yeast.

The action of ethylene in defoliating rosebushes, once a disadvantage, has now been turned into an advantage. When rosebushes are dug and held in cold storage, excessive loss of water from the plants may be prevented by defoliating. A very convenient way to do this is to treat the bushes with ethylene, or, if this is not practicable, the rosebushes may be stored along with apples. The procedure, although considered undesirable in the case of cut flowers, now becomes recommended for rosebushes. It is said that a commercial nurseryman on the West Coast has defoliated as many as 200,000 rosebushes, 50,000 in a single room, in four days' time. Customary methods would have required several weeks.

According to an article in *Tropical Agriculture*, ethylene has been used in Germany and in Italy for curing tobacco. Mature green leaves of tobacco, when treated with ethylene at the rate of 1 to 5,000 or 1 to 10,000, showed a yellow color earlier and more strongly than did those not treated. Flavor of the untreated sample was described as "sharp and poor" and the aroma "not

quite pure," whereas flavor of the treated lot was pronounced "rather full, not unpleasant" and the aroma, "pure, somewhat flowery."

Haber was able to induce earlier blooming of narcissus bulbs and the earlier maturing of sweet corn by the use of ethylene, but neither one of these uses has become a commercial practice.

As has been stated earlier, the ethylene first used was in smoke fumes, and later in fumes from a stove. It should be added that once again its usefulness in smoke has attracted notice. It has long been the custom in Hawaii to induce early flowering of pineapples by exposing them to wood smoke. As a result of the stimulating action of some substance in the smoke, the period required for maturing pineapple fruits was greatly reduced. In 1932 Rodriguez, in Puerto Rico, demonstrated that the active agent in the wood smoke was ethylene, and he was able to accomplish similar results with pure ethylene gas. Pineapple plants were thus made to bloom as much as six months before the normal time. Following this work, others treated pineapple plants with ethylene gas, with aqueous solutions of acetylene, or with pellets of calcium carbide, which generated acetylene when moistened by the dew on the plants. Some of these treatments for forcing the flowering of pineapple plants have now become commercial practices in Florida, with the result that these fruits can be produced out of season, when they command higher prices.

EXULTATION

From nameless peak to nameless peak
That men have yet to tally
My solitary song I fling
Across a nameless valley.

For here, within a secret world
By endless mountains bounded
From north to north, I stand alone
Where never song has sounded.

And in my blood the ardent strength
Of youth distills its thunder;
And as I sing, not I alone
But life cries out its wonder.

CLARENCE R. WYLIE, JR.

Book Reviews

AMERICAN SAGA

The Wallaces of Iowa. Russell Lord. xii + 615 pp. Illus. $5.00. Houghton Mifflin. New York. 1947.

IN DISCUSSING the lives and surroundings of three generations of Henry Wallaces, the author has assembled extracts from their writings, bits of anecdotal family history, and other interesting memorabilia. Many of these are in quotes in the text, others are quoted in a 14-page documentation. To these, the author has added his own first- and secondhand observations in and around the Department of Agriculture and Washington and then woven the whole more or less together with his own interpretations.

The plan of the book, as stated (p. 560), was to treat of the present Henry Wallace not as a chance growth, but as a product of an extraordinary heritage and upbringing, deeply aware of a genetic continuity in his every act. He is born about page 107. It is natural, therefore, that the 508 pages following his birth are increasingly devoted to this Henry's economic, political, and religious concepts and activities. Neither is it remarkable that the presentation is nearly, if not always, favorable to Henry Wallace and his ideas. The author was a sincere, though hired, propagandist (he calls it "special writer") for the New Deal agricultural policies. As his protagonism is frankly confessed, however, the reader can be on guard and discount some of the interpretations—if he knows which to discount and which to accept at face value.

Most readers of a book like this will have firsthand information on few, if any, of the facts and interpretations it contains. A single recognized distortion, whether intentional or not, accordingly shakes one's confidence in the whole, rendering it suspect. The reviewer had his frequently so shaken. Moreover, inaccuracies detected, even though they may be of minor importance to the main purpose of the book, have a similar effect. Thus, one does not inbreed corn to create hybrid vigor (pp. 146, 150). Again, "Some of the first hybrid seed corn" (facing p. 142) was not the first hybrid corn; that had been produced by others some years before. Neither was it the first commercial hybrid seed corn, as most readers would interpret the caption to mean; that was still to be produced, again by others than H. A. Wallace whose commercial production began many years later than the 1914 or 1915 implied on page 184. All these distortions make H. A. Wallace appear a far more important factor in corn breeding and hybrid corn development then he really was. They make a plant breeder wonder if the author is more accurate concerning other things about which he writes. Thus, for one example, on page 434 he refers to certain letters that "would have been belittling to the intelligence of an idiot child of ten" as being "forged." But can Mr. Lord's forgery allegation be relied upon any more than some of his loose statements about corn breeding? Does he know? Or is he guessing?

This reviewer may be unduly critical. He enjoyed reading of the early days in Iowa. He enjoyed reading of the bit actors in the agricultural New Deal as they passed from wing to wing across the national stage; he knew and liked many of them.

He would have enjoyed the book more, however, had it been more accurate about some of the facts with which the reviewer is familiar, and had it been written more objectively. The many quotations and extracts with which it is documented should give the book some continuing value. These are made more useful by an excellent index.

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CLIFF DWELLERS

The Pueblo Indians of San Ildefonso. William Whitman, 3rd. vii + 164 pp. $2.75. Columbia. New York. 1947.

THE pueblos of central and eastern New Mexico, the sedentary Indian villages that lie in the valley of the Rio Grande and its tributaries, are for anthropologists tantalizing and frustrating societies of tremendous scientific interest. They lie in our very midst and are manifestations of rich and elaborate cultures. They have been known to Europeans for more than four hundred years. They have been under American control for a century. They have been painted and sketched by many an artist. They have been visited by scores of anthropologists and investigated by a few. Yet we know very little about them in detail, and we do not have a full-fledged scientific study of even one of them.

This is because the people of the Eastern pueblos have drawn the protective mantle of secrecy about their ways. There are indications that even before the coming of the white man secrecy was the mark of these cultures. White contacts have only served to intensify the old aboriginal trait. A member of the pueblo knew what he needed to know to play his part in the balanced structure of the universe as it was conceived by his people. But no more.

Today, according to Dr. Whitman, the training of children in San Ildefonso is such that the young learn in time to cease to be outwardly curious, not to spy out the secrets of their elders. "The more esoteric aspects of the teachings are unknown except to the leaders . . . officers of one society do not know the sacred lore of other societies to which they do not belong. Both men and women fear the possession of unauthorized knowledge" (p. 117).

It is easy to understand that such people are not receptive to prying anthropological investigation. Almost any data on the Eastern pueblos are, if reliable, useful contributions to science. Dr. Whitman's data, though scanty, are sound and presented with cautious restraint.

This book on San Ildefonso is no monumental monograph. Rather, it is a charmingly written little summary of the more superficial aspects of San Ildefonso life as observed by the author in a year's residence in the pueblo with his wife and three children. There is good material on government, fairly intimate descriptions of family life and personalities, and useful information on the externals of pueblo economics. But on religion, which, in the words of the author, "more than anything else is the integrating factor in San Ildefonso society," there is virtually nothing. Dr. Whitman did not want to get thrown out of the pueblo for asking questions out of turn. His problem was limited to observation of nonesoteric behavior. He makes no claim to definitiveness.

San Ildefonso has become famous throughout the land for its modern black-glazed pottery, formed by the women and painted by the men. An introduction to the lives of these skilled artisans will be found in the book.

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SCIENCE OF THE SEA

This Great and Wide Sea. R. E. Coker. xvii+325 pp. $5.00. Univ. of North Carolina. Chapel Hill. 1947.

A PEOPLE made ocean-conscious by the catastrophe they have just lived through should welcome this popularized yet comprehensive treatise on the science of the sea. Oceanography is here wisely conceived as "the study of the sea in all its aspects." It is said, however, not to be a science in itself. That point I would modify, for any science is knowledge set to order and to use, about any focus, and no science is self-contained. The degree to which the facts and interpretations that pertain to the sea are integrated measures how justified it is to regard oceanography as a science. This book demonstrates that considerable success has been attained in such integration. In fact, it helps establish the science, while recognizing that "hardly any phenomenon of the sea is capable of satisfactory analysis without coordination of all fundamental sciences."

The history of oceanography is readably and adequately treated, with just a bit of romance and religion thrown in. The emphasis is on the evolution of the science, in terms of methods and concepts as well as of accumulated facts. General orientation is completed by a brief description of the geography of the sea.

The physical and the biological aspects of ocean science are accorded about equal space and equal emphasis. The first section deals with the sea as a solution; physical properties of sea water; bottom deposits; plans of circulation; wind-induced, tidal, and other movements; the sea and the sun. As a whole this section is accurate, informative, and reasonably adequate for all except specialists. Some complicated phenomena, such as currents and tides, are made surprisingly clear considering the purge of mathematics. Certain statements, however, seem unnecessarily conservative, and the treatment of some subjects seems unduly simplified. The representation of the distribution of temperature from pole to pole is not only schematic as stated, and unnecessarily hypothetical, but is also misleading in that it fails to show the fundamentally important north-south asymmetry in temperature distribution. Due emphasis is not granted to the importance of the bathythermograph and of other apparatus developed during the war. Oddly, the grossly macrocephalic sperm whale is chosen as "a notable example of good stream-line form." The tuna would have served much better.

In the biological section there is a fairly complete, interesting, and well-illustrated account of marine life. Particularly well done are the contrasts between the ecology of the sea and that of fresh waters. Full success was not attained—it was hardly to be expected—in the effort to eliminate the inconsistencies and the lack of logic that have always marked the classification of marine habitats and biotic assemblages. "Benthos" is used in two senses, with a differentiation only of the adjective forms, which are usually defined as synonymous. "Benthonic" is applied to any bottom life; "benthic" only to that of the continental slope. "Littoral" is adopted in the wide sense, with divisions into "intertidal" (with no mention of a supratidal or spray belt), "eulittoral" (from low tide to the limit of plant growth), and "sublittoral" (thence to the edge of the continental shelf). "Nekton" is defined as free-swimming pelagic life, yet all adult fishes are included (following, to be sure, other treatments, including that of *The Oceans*). If the concept of the "benthos" means anything, whatever it may be called, it surely should include at least the bottom-resting flatfishes and rays, the burrowing gobies, the rock-crevice sculpins and blennies, the species that are closely associated

with plants, and many other fishes. To be sure, there are many fishes that grade from "benthonic" to neritic, but such transitions are the rule. Ecological ties should mean more than locomotor habits. If the proposed division of the bottom life into "edreobenthos" (strictly attached) and "herpetobenthos" (crawling) should be adopted, it appears that there should be added a "nektobenthos" (swimming). These, of course, all intergrade.

Errors, in general, are almost negligible, except in the section on fishes. Here the incongruous and long-discredited classification of Boulenger is adopted (from Murray and Hjort). The life term of the leptocephalus of the American eel is given as two years, following an error that crept into *The Oceans*. Unaccountably, a picture of a ctenophore is presented as that of a leptocephalus. The figure labeled "flying fish" is that of a sea robin, not even that of a flying gurnard (which never flies). The flaplike lure of the goosefish is wrongly called a light organ. *Mola* is said to be rare and is otherwise wrongly characterized. *Ophiodon* is classed in the cod family.

A new edition should take care of such errors. To wind up adverse, and perhaps pedantic, criticisms, I note an overemphasis on the significance of variations in the dissolved oxygen content of shallow waters, some erroneous derivations of technical terms, and, in places, an unnecessarily cautious approach, marked by the insertion of "possibly" or "probably" where facts are well established. Naturally, examples are often drawn from, and presentations colored by, the author's personal contacts with the sea at Beaufort, N. C., and in Peru.

But who, except for a team of authorities, checked by another team, could have compiled without errors and inadequacies such a comprehensive treatise on a very complex and as yet not thoroughly integrated science? Coker set himself to the task of filling a great need, and this he accomplished very creditably. In fact, he filled a series of wants, for the book will serve well as an elementary text in oceanography, as collateral reading in courses in geography and in biology; above all, as a general source of information on a broad and fascinating subject.

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CHEMICAL PERSPECTIVE

Modern Chemistry: Some Sketches of Its Historical Development. A. J. Berry. x+240 pp. $2.50. Cambridge. Cambridge, Eng. Macmillan. New York. 1946.

THIS little book makes no attempt to deal with the history of the whole of chemistry, nor is it based on a strictly chronological plan. Instead the author follows the historical development of each of several branches of chemical study in separate chapters covering atomic theory, electrochemistry, stereochemistry, radioactivity, elements and isotopes, experimental studies on gases, some problems of solutions, chemical dynamics, and the development of physical chemistry. In his preface the author states:

> An attempt has been made to consider the development in historical perspective of certain branches of the science in separate chapters—each being nearly self-contained and largely independent of the others—and treated in a manner so as to be acceptable to anyone who is endowed with a moderate stock of chemical knowledge. To have attempted the writing of a more formal history of modern chemistry at the present time would have been a somewhat unsatisfactory task—it has been considered better to abandon some branches of the science altogether, rather than to attempt any sort of ill-digested completeness. . . . It is hoped that the division according to branches of study rather than according to periods of time will be found more interesting and certainly more convenient, from the point of view of the student.

The period covered by this book begins early in the nineteenth century and extends up to date as of 1944. The table of contents is unusually complete, amounting to a highly condensed topical abstract. A short list of references accompanies each chapter, representing the author's selection of the most important source material. An index of proper names and an index of subjects is also provided. The author has presented his subject matter in a very readable style while at the same time presenting a wealth of factual detail. The book is a contribution in support of the notion that a right attitude toward any subject should include a knowledge of the order in which men have perceived and tackled the problems it presented.

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OLD WINE IN A NEW JACKET

Handbook of the Trees of the Northern States and Canada East of the Rocky Mountains. Romeyn Beck Hough. x+470 pp. Illus. $5.50. Macmillan. New York. 1947.

IT WOULD be interesting to have at hand the reviews of Mr. Hough's *Handbook of Trees* that appeared on its publication in 1907, to see how in that far-off time of one's infancy reviewers responded to the first publication of this work. The comparison would surely be valid, for apparently the only difference now is in the type on the title page, though bindings may have been sturdier in those hardy days. Men's palms, too, must have been larger in the era when this work was christened a "handbook." It is an excellent book, however, giving the botanical characters and a 250-word general account for each of more than 200 trees. Surrounding the type are photographs (totaling 479 in the book, according to its jacket) and a range map on facing pages, thus wherever the book is opened presenting the complete account of some tree. After all, trees have not changed much in one of man's generations, and unfortunately there is still validity in such a comment as "The Hemlock . . . was once one of the most abundant trees of the northeastern forest, but such is the value of its bark for tanning purposes that they have nearly all been destroyed, only scattering trees now remaining." Mr. Hough, however, deliberately missed the forest to show trees, and those who are interested in trees will indeed have a good chance to see them in this book, though one will have to be careful in relying on it for a vocabulary with which to talk up to technical foresters. The trees are the same, but the scientists in forty years, it can be taken for granted, have thought up a few new names and discovered at least some corrections in classification.

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THE AGE OF ANXIETY

The Problem of Reducing Vulnerability to Atomic Bombs. Ansley J. Coale. xii + 116 pp. $2.00. Princeton. Princeton, N. J. 1947.

SEVERAL books have been written upon atomic energy since the Smyth Report in 1945. The vast majority of them have described the Smyth Report in simpler words, with a modicum of speculation regarding the influence of atomic energy on various phases of life. Few books, however, have been of such importance that they stand out as key publications for policy making and as directives for future efforts. The Smyth and the Acheson-Lilienthal reports were definitely important publications regarding atomic energy, but both of them failed to present a concise and

well-worked out scheme for a nation faced with the possible use of atomic energy in an all-out atomic war. This lack has been remedied by Coale's book, which was prepared under the direction of the Committee on Social and Economic Aspects of Atomic Energy, of the Social Science Research Council (Riefler, Brodie, Likert, Marschak, Notestein, Ogburn, Rabi, and Smyth). An objective attitude is maintained throughout the book.

The four sections, labeled chapters, begin with Reduction of Vulnerability Under an Effective Agreement, which is a detailed study of the vulnerability of a nation under a surprise attack from a supposedly peaceful and friendly country. The aggressor nation would have secretly diverted fissionable material to manufacture atomic bombs. Important defense measures would include maintaining the armed forces at a high peak, stock-piling strategic materials, and reducing the vulnerability of the country to attack. An entirely new mode of warfare, of disposal of troops and materials, and a new method of handling munitions would be essential. There is strong evidence that the war might be won or lost on the munitions stock-piled at the time of the attack. The disruption resulting from an all-out atomic attack might leave only especially prepared, secret, underground production centers capable of fighting back.

The section on Reduction of Vulnerability when Atomic Armament is Unlimited is very pertinent to present world conditions. The use of X-thousand atomic bombs in an all-out atomic attack presents two problems: one, a loss of the war if special provisions against impending attack have not been strictly enforced; and, two, the probable loss of humanity if radioactive by-products cover the earth. The latter point is not discussed to any extent. One solution would be to stagger the use of atomic bombs so as to give time for the radioactive products to decay below the lethal point for the total atmosphere. There is always the possibility, of course, that one nation would disregard such an action and precipitate a biological crisis. Relocation of industry and living centers is mentioned as a means of reducing casualties. The magnitude of such a task, as described, precludes any hope of its being done until after at least one atomic war has been fought. The casualties in such a war would be high, perhaps one-third of the total population of the United States in the first week or so.

Technical Considerations goes into detail on points covered by the Smyth report and subsequent releases on the attacks on Japan and the Bikini tests. Blast, radiant heat, and penetrating radiation remove the atomic bomb from the category of any previously used weapon. Furthermore, bombs can be made many times more destructive than any used so far. More powerful bombs would prohibit the use of underground emplacements for defense as well as for living quarters. Knowledge of the location of such an underground point would be all that would be necessary to ensure its destruction. The method of delivery is assumed to be, primarily, the plane. The use of supersonic missiles such as the V-2 type of rocket would make any attempt at interception almost useless.

The important fact is brought out that defense against chemical missiles is considered partially successful, but that only one atomic warhead getting through means destruction of the target and the surrounding area. First-used defenses are always ineffective, which, in the case of atomic warheads, almost eliminates any form of defense against them. A 100-percent effective defense from the beginning of an attack is technically and mechanically impossible within our present scope of knowledge. Radioactive and biological poisons are very briefly discussed. Most scientists believe that they are just as effective as the atomic

bomb—if not more so. The unshielded-pile jet plane is not emphasized. This latter weapon would be very efficacious.

The last chapter, or section, is on the need for research and analysis. The weakness of modern civilization, faced with the threat of atomic warfare, lies, of course, in its centralized location of communications, government, and production. The discussion of this factor and of decentralization convinces one that atomic warfare and an advanced civilization are mutually incompatible.

This well-written, important book is a must for anyone interested in his future chance of survival. The general conclusion is that an atomic war would be so destructive that any country indulging in it probably would not recover. The greatest handicap to an effective defense seems to be psychological. Everyone assumes that "it can't happen here." Such an attitude almost automatically wipes out really adequate countermeasures. Although the United States is used as an example of the attacked nation, there is very little doubt that an aggressor nation would be confronted with similar problems. Coale emphasizes the fact that no nation would risk an atomic war unless it were reasonably certain that retaliation in kind would be impossible. This premise, however, has been held by all aggressor nations and has always proved futile. It should not be overlooked that even in the case of the defeat of a country by atomic warfare, the radioactive by-products, the biological pests released, and the underground resistance using such weapons would eventually destroy the attacker just as efficiently as if he had been destroyed in the beginning. The question is one of time, and of more academic interest than technical at the moment.

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BIRDS

Darwin's Finches. David Lack. x + 208 pp. Illus. $4.50. Cambridge. Cambridge, Eng. Macmillan. New York. 1947.

ADAPTATION of form to function has been a favorite theme for the biologist. Textbooks and manuals explain how the larger groups of birds show differences in feet, beaks, etc., adapted to their ways of life. The finches of the Galapagos Islands came first to attention from Darwin's *Voyage of the Beagle.* They interested him immensely and had a prominent part in developing his ideas of natural selection. Contrary to ancient development of the larger groups, this is a relatively modern branch in which *species,* closely related, have diverged to show surprising differences in beaks and feeding habits. A cuckoo, mockingbird, warbler, martin, and two flycatchers, comprising the rest of the Galapagos land birds, are closely related to South American forms and are believed to have reached the islands accidentally at various periods.

Lack presents a concise summary, from a brief general description of the islands and their human history to detailed analyses of specimens in various museums and of behavior as reported by all expeditions. Colored illustrations of seven species are reproduced from Gould's work, which had first described the birds from Darwin's collection.

Previous authors have held that beak differences in species of *Geospiza* are not of adaptive significance in regard to food. Lack feels that there must be small differences that are sufficient, at least at some period, to prevent competition between species. Earlier analyses failed to give enough weight to food habits during the breeding season. Lack considers also that beak differences play an essential role as recognition marks. Similar differences in

bill size for other species of island birds are discussed. The beak of the Galapagos mockingbird varies in length from 20 mm. on some islands to 33 mm. on others, a range which scarcely seems possible to attribute to differences in food habits.

Camarhynchus pallidus, the woodpecker finch, climbs up and down tree trunks. It has a somewhat elongated beak, with which it drills for insects but, lacking the long tongue of a woodpecker, it takes a cactus spine or slender twig and probes for insects. This habit, observed by Gifford in 1919, by W. H. Thompson, and by Lack, is said to be one of the few recorded uses of tools by birds.

Lack recognizes fourteen species in four genera. He seems not to indicate any formal technical changes in status but has some notes in Table IV. Two forms collected by Darwin are regarded as extinct subspecies, but are not formally named. He feels that hybridization has not been frequent, but regards intermediate specimens as unusual extremes. The final chapters deal with origin of the Galapagos fauna, origin of species and subspecies, persistence of species, and adaptive radiation. There is a good index and an extended list of references.

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WEALTH OF THE OCEAN

Raw Materials from the Sea. E. Frankland Armstrong and L. Mackenzie Miall. xii + 196 pp. Illus. $3.75. Chemical Pub. Brooklyn. 1947.

THIS book describes the separation of economically important substances from the sea and includes "general reference fo the chemical problems which the oceans represent and to the various elements in them in minor quantities." The first chapters—Something about the Oceans, Chemicals in the Sea, and The Bio-chemistry of the Ocean—are compilations of marine fact. The remainder of the volume considers the separation of materials from the sea: Solar Salt, Bromine from the Sea, Magnesium from the Sea, Iodine and the Seaweed Industry, Potassium Salts, and Potable Water from Sea Water. Many references are given; an appendix on analytical methods and an index complete the work.

While this volume is neither nontechnical enough to be a popular work nor critical enough to satisfy the requirements of a source book, it does offer a rounded orientation toward its subject. In this respect it represents a contribution to chemical literature, but in others it does not reach the standard common to the field. Editorial and typographical errors are frequent, and the appendix on analytical methods serves little purpose since this twelve-page précis of analytical procedures for twenty-four elements cannot be used in the laboratory and offers no critical focus for the reader.

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THE FRENCH-CANADIAN OUTLOOK

A Brief Account of the Unknown North Americans. Mason Wade. 192 pp. $2.00. Viking. New York. 1946.

MASON WADE has written for the general public a little book which contains some of the observations and conclusions that will later appear in what will prove to be a "monumental" work on the French-Canadian mentality. Such an enterprise is always risky: the observations are likely to appear a little short, the conclusions gratuitous; and the plan itself is revealed as through the large end of a

telescope. One may not, therefore, quarrel with Wade over some of his more evident simplifications, nor reproach him for avoiding some rather involved issues, but rather wait until the promised big book is published. He has probably brought together in the present volume the most extensive existing documentation on this subject, and has obviously done so in a spirit of objectivity and fairness.

Wade's training as a historian and his previous record as a writer provide him with an especially desirable background for this delicate task. His interest in the work of Francis Parkman early brought his attention to the conflict between French and English in the St. Lawrence Valley. This has enabled him to bring out the historical filiation of some of the debates that endure in one form or another to this day. For instance, in many passages, he picks up the thread of ultramontanism in the French-Canadian clergy and people and shows that it amounts to a veritable tradition and is to be considered one of the basic traits of this people's mentality. This is one of the most important themes in his book and one of the most valid explanations of many an attitude of French-Canadian leaders of the past and present.

The first chapter is a most important one to those who seek to understand French Canadians, inasmuch as they "live in and on their past to a degree almost inconceivable to the average English-speaking North American; .. tradition is a stronger force there today than anywhere else in North America." What French Canadians think and know of their past is almost as important, as a motive, as what really happened. Wade has had to do some first-rate debunking to show that the wishful thinking of both French- and English-speaking historians has led to the writing of "histories of Canada so dissimilar as to suggest that they were histories of two different countries." Crusading colonization, romantic gentility, fearless adventure, bold resistance, desperate courage—such are the elements of his history to the French Canadian, to whom the inherent weaknesses of the French Regime do not appear any too clearly and even less the contrast between its social structure and that of New England, say. Wade justly remarks upon the "hierarchical society" of New France and on how it has tenaciously survived. In fact, the picture painted by Pehr Kalm in the latter part of the eighteenth century remains true in its basic elements. This, in a concluding chapter, is summed up in the following sentences:

> French-Canadian society varies notably from the North American norm. It may well be compared to an iceberg. The one-ninth that is above water, the elite of priests, lawyers, doctors, scholars, and other highly educated men includes some of the most cultivated and charming human beings on this continent. Most of its members are the equals and some the superiors of the best that English-speaking North America produces. The humanistic discipline of the classical colleges has preserved them from the narrow and limited outlook increasingly characteristic of products of the English-speaking educational system, as premature specialization and overemphasis on technical studies have become more and more dominant. Perfectly bilingual, at home with the cultural heritages of France, Britain, and the United States, and adding Gallic gaiety and wit to the North American mixture of traits, the best of this elite is a leavening element in Canada, and can be one throughout North America if it develops a broader outlook and continues to strengthen its technical training. But the submerged eight-ninths of the social iceberg, the great mass of the French Canadian, are underprivileged economically and intellectually. Their standard of living is well below the North American norm; and has become dangerously so as more and more of them abandon rural life with its low cash income compensated by good food and health, in favor of higher wages with poorer food and housing in the overcrowded cities, where malnutrition and tuberculosis have made great inroads on the traditional French-Canadian vitality.

To many of us the above seems somewhat oversimplified, and there have been

rather vigorous and not entirely judicious protests. But it may be that we live too close to ourselves to get the proper perspective.

The first contacts between French and English, which are described in the second chapter, were not all unhappy. It is an established fact that the majority of the conquered French cared more for the land they inhabited than for allegiance to France. In fact, it is noteworthy that no movement of any significance was ever undertaken in the direction of a return to France, and that the French Canadians struggled to remain distinct, to maintain their language and religion, not to free themselves from British rule.

The period from 1790 to 1867 is much more difficult to summarize and involves a number of new elements. The author does his best to dispel some of the more current misconceptions concerning the French Canadians and urges that "it never be forgotten that the French Canadians are North Americans, and that they have been exposed to North American influences longer than have either Americans or English Canadians."

The crucial event of the difficult and unhappy pre-Confederation period is the suppressed revolution of 1837–38, which the author characterizes in these Churchillian terms: "Never has so little bloodshed been so well remembered." "Ethnic hatred," however, was not the only issue, and the economy that emerged from that crisis was not one to cause French Canadians to rejoice. Contradictory ideals, culture, religion, and economic standards made it hard for "two peoples to make a nation." That they nevertheless did, through a common, if mutually ignored, desire to achieve a livable adaptation to their North American environment.

The third period, ending with World War I, is notable, however, for a decadence of the spirit of Confederation, whose "survival has frequently been threatened by the failure of later leaders to share the tolerant spirit of the fathers of Confederation." An excessive cultivation of the past and a spirit of grievance on one side, lack of understanding and economic oppression on the other, were such that "relations between French and English Canadians reached a new low in the closing years of the First World War."

During the interval between the two world wars, the French-Canadian isolationists turned briefly to separatism as a goal to be achieved in Quebec, only to defeat themselves during World War II. The all-out imperialists and implicitly racist money-makers also encountered their day of liquidation in the changing world economy.

Another French-Canadian myth is the sacredness and the "goodness" of the soil, coupled with "the resistance of the class-proud elite to any occupation which involved rolling up one's sleeves and getting one's hands dirty." Attachment to the soil and the moral values rural life is supposed to stand for are an important part of the French-Canadian emotional background. On the other hand, the "classical" pattern of education tends to strengthen the social hierarchy. These and many other factors of the French-Canadian complex are taken into account by Wade in his survey when, in his final chapter, he attempts to draw together the threads of French-Canadian history and social and economic life.

The picture, as it stands, therefore, is not meant to please or to displease, but mainly to inform. The book should prove extremely useful to many categories of readers. As the author points out in his concluding remarks: "The problem of Canadian union is merely a special case of the great world problem of our time." And that is everybody's business.

PIERRE DANSEREAU

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Comments and Criticisms

GHOST WORDS

Mr. Thomson King undertakes to show your readers that life is a "separate entity." By separate he means that it is not matter and not energy, which, he says, are the only other two "entities;" as it is not either of them, it must be a separate "entity." Matter and energy, he says, "have their usual scientific meanings;" while by "entity" he means something "having reality in fact, which is separate and unique in itself."

Some of your readers, of whom I am one, will doubtless consider this alleged definition not wholly satisfying. Pushed into a corner, Mr. King would be compelled to confess that he does not know how to define "entity," that it is but a ghost word, a concoction of the medieval Schoolmen, without any real content, and satirized by Butler in "Hudibras,"

> Where entity and quiddity,
> The ghosts of defunct bodies, fly.

Looking in the *Century Dictionary*, we find that it is "an ontological chimera" and "an independent ens."

Once in a class at college, I was assigned to write an essay on matter. I spent an hour or two in the university library copying down the opinions of many learned men on the subject; my conclusion was that there is no true definition of matter. Mr. King slides out of this dilemma by saying merely, "It has its usual scientific meaning."

Mr. King's essay, as an essay, may have some collateral value; but, as to the nature of life, he has told us nothing and our knowledge remains what it always was: we do not know what life is and we have no way of finding out. The nearest thing I know to a definition is that given in Wilhelm Bölsche's "Stunden im All" (and doubtless by others, too) in which he compares life to a candle flame; Mr. King can best tell whether that meets his definition of an entity. The string of startling scholia that draws out of his main thesis will, of course, fall to the ground along with it.

Even a god could not give us a true definition of life, for it would be beyond our comprehension; and, as the author of "Shakespeare" [*sic*] succinctly put it,

> We fools of nature
> So horridly to shake our dispositions
> With thoughts beyond the reaches of our souls.

WETMORE COLLES

Rosharon, Tex.

LE PROBLÈME DE L'UTRICULAIRE

Permit me to express my appreciation of an article in the May number of THE SCIENTIFIC MONTHLY, by E. W. Gudger, on *Utricularia vulgaris* L. as a fish-catching plant.

Am more interested from the botanist's view than from that of the ichthyologist, but found the article very interesting and rather complete, conservative and readable.

Have had occasion to study the plant at first-hand, as I own several small lakes where two species of *Utricularia* are in bloom in July and August. These are *Utricularia vulgaris and U. radiata.* Will watch these with even more interest now.

A recent English authority goes further in stating that *Utricularia vulgaris* catches its prey and completely digests it in twenty minutes, then sets the trap for the next victim (Brimble, L. J. F. *Flowers in Britain.* London: 1944). Brimble is joint editor of *Nature* and Lecturer, Universities of Glasgow and Manchester.

Thanks again for publishing readable articles of this nature.

S. G. DRUSHEL

Edna, Texas

OF CHAOS AND COSMOS

In the June issue Mr. John L. Chambliss' "A Layman Looks at Science" states Sir James Jeans's tidal disruption theory as explaining the origin of the solar system by "the *chance* approach of a passing star." Now, obviously, all that the theory postulates is the approach of a star to the sun near enough to detach a fragment capable of segregating into the planetary system, and the theory is entirely unaffected by the cause of the approach. Whether the event was controlled by Chance or by Design is, in respect of the result, of no meaning. It follows, therefore, that any eventual confirmation of Jeans's hypothesis would afford no ground for Mr. Chambliss' fear that, "if we thus account for the origin of the solar system and this earth we live on, then the idea of a Guiding Intelligence behind the universe goes up in a puff of smoke."

Natural science is concerned with the forces associated with the sun and the visiting stars, but the Power directing those forces is the subject of an inquiry lying entirely outside its scope.

HENRY H. KNOX

Santa Barbara, Calif.

PSYCHOLOGICAL PHENOMENON

It is difficult to express soberly my disappointment concerning Mather's review (SM, May 1947) after reading Du Noüy's *Human Destiny*. Mather's only important criticism, that the author "at times seems to base certain conclusions on the absence of knowledge rather than upon inferences from verifiable data," is sound, but understated.

If the book is not to be called intellectually dishonest, it must be classed as an example of the psychological phenomenon described by Carlson in "Science and the Supernatural" (SM, August 1944): "The two [science and the supernatural] are in their very essence imcompatible, but they can apparently coexist in some scientists of the first rank. Man is, indeed, a perplexing animal."

Although the book is confused and contradictory, its chief error is quite clear. This is a misconception of the scientific attitude, a claim that science is no longer deterministic, and has no laws other than statistical ones. On page 26 is found this amazing statement: "*All* our scientific laws at present rest on chance, that is to say, on the hypothesis of an absolute disorder at the base." This denies the existence of gravitational and other field theories, and most other physical theories, including the basic principles of the conservation of momentum and of mass-energy, yet its author is said to be "one of the foremost biophysicists of our time."

Du Noüy also makes mistakes in applying the calculus of probabilities, which he claims is the basis of scientific law. The first is the assumption (p. 33) that all dissymmetries of molecules are due to chance, not to the nature of the bonds between atoms. The last is the conclusion that an event with an extremely small, but finite, probability never could happen, even in an infinite time (p. 35). This confusion of infinity with something finite is repeated on pages 66, 121 (twice), 122, 177, 192, and 193.

Having denied the existence of the first law of thermodynamics, Du Noüy proceeds to misapply the second law. Although the limitation of this law to *isolated* systems is correctly stated in a footnote on page 41, it is repeatedly applied to nonisolated systems—as living things always are—thereby arriving at false conclusions like (pp. 41–42) "The laws of chance forbid any evolution other than that which leads to less and less dissymmetrical states." If this law be thus misapplied, one need not go to living matter to find violations of it. Even such an unthinking thing as an electric motor is a perpetual motion machine—as long as it is connected to a power source! If a student in a thermodynamics class showed such poor understanding of the second law he would be promptly "flunked." When "one of the foremost biophysicists of our time" does it, his book becomes a best seller, and is praised by Nobel prize-winner Millikan as "a book of . . . fundamental grasp and insight." Carlson was right; man *is* a perplexing animal!

Though he distorts the deterministic attitude in his attacks on it, it is significant that Du Noüy himself, in the work that brought him his scientific reputation, was using the deterministic point of view. See, for example, the chapter ' Surface Tension of Colloidal Solutions, and Dimensions of Certain Organic Molecules" which Du Noüy contributed to J. Alexander's *Colloid Chemistry*. It shows the same materialistic attitude as the other chapters.

If space permitted, I could cite many more instances in *Human Destiny* where its author shows a misunderstanding of the aim of science, modern theories of evolution, even religion, although the book is obviously an apology for religion. However, the book is not all bad. The discussion of education in Chapter 15 has some good points, though even this is marred by many dogmatic assertions on debatable topics.

GEORGE A. FINK

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ETERNAL TRUTHS

It is indeed refreshing to read the meditations of the young surgeon expressed in the poem "To a Cadaver," by Arden Almquist, in the April issue of THE SCIENTIFIC MONTHLY. In this age when many misguided souls close their minds to eternal truths, refusing to be convinced by facts evident even in their own poor experiments, it is heartening to recognize a man who loves all men for the very dignity that is theirs as children of God.

HARRIET GRIFFIN

Brooklyn, N. Y.

VALUES

I write, as a humanistic philosopher, to express my hearty admiration for, and concurrence in, "The Scope of Science," by Ralph W. Gerard [SM, June 1947]. And, incidentally, to congratulate you on the greater interest afforded by the recent widened scope of your journal.

J. A. LEIGHTON

Worthington, Ohio

Technological Notes

Too Much of a Good Thing. Experience as an "information specialist" has made me sympathetic with the efforts of the people who are trying to write informative newspaper stories about the work they are hired to publicize. I am particularly interested in attempts to tell people about scientific developments and applications. Most of us believe that more and better science writing is needed.

Perhaps we are wrong—at least about "more" writing. Anyhow, the combination of a hot August afternoon and a bale of releases has made me skeptical.

When I studied civil engineering at Ohio State University the chairman of the department, Professor "Chris" Sherman, instructed us in some details of life as well as of technology. The technology is largely gone, but some of the life lessons remain, with this in first place: If we are doing any engineering work we want every technical detail to be the best possible. We want accurate plans, excellent construction, intelligent supervision, precise inspection. But the most important engineering decision of the entire project is whether the work ought to be done at all.

That criterion comes to mind as I look over eighteen offerings of the "Public Information Service" for the annual convention of the American Society of Civil Engineers in Duluth last July. Obviously, the public-relations people didn't expect every editor to use every story. There was repetition. Nearly every piece mentioned the "94-year-old society, oldest national engineering organization in the country." (Though 1852 from 1947 leaves 95.) A general story gave names and titles of papers, and other articles gave details of individual talks. There was variety and information, but the depressing thought remains that most of the carefully prepared material reached editors' wastebaskets instead of readers.

It appears that the ASCE program was interesting. There was reassurance—Minnesota's iron ore won't give out for a long time, for when we need it we can concentrate the lean deposits, even burning nearby peat for power, as the Russians are now doing. There was the usual prodding of the members to assert themselves as citizens as well as engineers. Timber management was urged, as well as engineering knowledge of plywood; diversion of water to useful places was compared to a blood transfusion; war haste in placing concrete was deplored; the Garrison Dam project was called "heart and keystone" of Missouri River development; Maine's building of a toll road, like Maine politics, was suggested as a national pattern (wait and see whether it pays, though); the U. S. Engineers are learning how to build on "permafrost," the permanently frozen ground up North; construction costs can't come down to prewar—we can't pay the national debt if they do; chemical treatments make earth highway bases almost prescription items; bold city planning is needed to free us from the tyranny of gridiron street patterns; the building industry needs a research program; Duluth-Superior harbor is next to New York's in tonnage; Minnesota has a fifteen-million-dollar sewage-disposal program.

Valuable items those. Good for people to know. But eighteen separate releases about them make the dose rather heavy.—M. W.

The Brownstone Tower

MEMBER participation is the key to a more interesting, more informative, and more authoritative SM and to a stronger, more influential A.A.A.S. The trend is in that direction, as indicated by developments that occurred during the summer.

Our plan to re-establish Science on the March, beginning in the January 1948 issue, on a broad, firm basis of member participation is getting a splendid response. We wrote to the presidents of sixty societies affiliated with the A.A.A.S. requesting them to appoint one or more reporters to represent their societies in Science on the March. At this writing in August many reporters have already accepted appointment, and many others are to be appointed at forthcoming meetings of the governing bodies of certain societies. Every reporter is to submit at least one short article each year describing some significant advances in the field of science covered by his society. Thus we shall get more comprehensive coverage of all fields of science than was heretofore possible. Moreover, these reporters, all chosen because of their familiarity with their subjects and their ability to write in a nontechnical manner, may write principal articles or call attention to articles that should be written for the SM. Their services as advisers to the editor may be just as valuable as their contributions to Science on the March.

Another form of member participation is developing through the first photographic competition being sponsored by the SM and the Smithsonian Institution. Many requests for information have been received, and entries for the competition are beginning to arrive. Thus the SM will make possible the public showing of selected prints of special scientific merit, not only in the Smithsonian Institution and at the Chicago meeting, but subsequently in institutions that may wish to borrow the prints for limited periods. These exhibitions, together with the publication of selected prints in the SM, should call attention far and wide to the uses of photography in scientific research.

The SM has already served as an outlet for other forms of expression by scientists. Examples of serious poetry and light verse written by scientists have appeared regularly. What about the graphic arts? Here again member participation may provide satisfaction to the participants and increase the attractiveness of the SM. We should be glad to receive artistic black-and-white sketches of a literal or symbolic nature that might be used as headpieces or tailpieces or elsewhere in the SM as space and appropriateness may dictate. Any scientist gifted in sketching can see by looking at the present SM how much its appearance could be improved by appropriate artistic decoration. We should be glad to have the ideas of members on this subject whether they can contribute sketches or not.

The steadfastness of our readers will soon receive a severe test—one that touches the pocketbook. On page 294 of this issue is the announcement of an increase in annual dues to the A.A.A.S. from $5.00 to $6.50, effective for the SM to be delivered in 1948. Our Executive Committee held off this increase as long as possible, but the effect of rising prices could not be denied. Let us work together to make the SM well worth its increased cost.

F. L. CAMPBELL